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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

VOL. 2. NO. 4.

DECEMBER, 1945

THE TOXICITY OF YELLOW-WOOD (*Terminalia oblongata*) TO CATTLE.

By JOHN LEGG, B.Sc., D.V.Sc., M.R.C.V.S., Acting Director, G. R. MOULE, B.V.Sc., Veterinary Officer, and R. D. CHESTER, B.V.Sc., Veterinary Officer, Division of Animal Industry.

SUMMARY.

1. *Feeding tests were carried out with yellow-wood, which was suspected of poisoning cattle in central Queensland, producing a subacute to chronic disease characterized by emaciation, photophobia and frequent urination.*

2. *All animals fed on yellow-wood leaves exhibited symptoms differing only slightly from those observed in natural cases, and yellow-wood is therefore regarded as the cause of the trouble.*

3. *The main lesion is a parenchymatous nephritis.*

INTRODUCTION.

A peculiar disease of cattle has been observed for very many years in certain parts of the Fitzroy River basin in central Queensland. It has been stated that in dry years losses of as much as 10 per cent. of the stock, including a high proportion of young cattle, have occurred on some affected properties, while even in relatively good seasons the disease is present during the drier months of the year.

During 1940 and 1941, field surveys of the affected area were carried out by the district Departmental Veterinary Officer. These surveys (Irving, 1940, 1941) indicated that the disease was apparently confined to a particular type of country and suggested that a poisonous plant—probably yellow-wood (*Terminalia oblongata*)—was involved. Following a botanical survey of properties on which the disease was known to occur, Francis (1941) reported that in his opinion, of nine species widely distributed, commonly eaten and known to be toxic to livestock, yellow-wood was to be most suspected. He pointed out that the geographical distribution of this plant was fairly close in its limits to the area in which the disease occurred and that it was abundant on affected properties. Further, it was well known to be eaten by stock in fairly large quantities during dry periods—in fact, it has been regarded by many landholders as a useful fodder, particularly in times of

drought. Finally, the plant had been shown by McIntosh (1934) to be poisonous to sheep, though the syndrome shown by cattle does not resemble that exhibited by sheep, which show a peculiar train of nervous symptoms.

In view of the suspicion attached to yellow-wood as the cause of the disease condition peculiar to the Fitzroy River basin, it was decided to conduct feeding tests with cattle. These were carried out at Clermont, in central Queensland, during the winter months of 1944 and are reported upon later in this paper.

DESCRIPTION OF THE YELLOW-WOOD PLANT.

Terminalia oblongata is a large shrub or small tree of rather dense growth. The leaves are 1–2 inches long, of a light-green colour, and commonly borne in clusters along the stems. The flowers are insignificant and are carried in short spikes. The fruit or seed capsule is dry and its sides are extended into broad wings, the whole capsule, including the wings, being about 1 inch broad. The plant coppices very freely at the base of the trunk.

The plant is apparently confined to Queensland, where it has a fairly wide distribution in the central and northern coastal and sub-coastal areas. Collection localities include Rockhampton, the Suttor and McKenzie River basins, the Burdekin River, Springsure, and the Belyando River.

OCCURRENCE AND SYMPTOMS OF THE NATURAL DISEASE.

Mortalities occur at all seasons but are most common during dry periods; hence sick animals are most frequently encountered between June and December.

The condition is not restricted to any one sex or age group of cattle, but it does not occur in calves which have not commenced to graze.

The symptoms presented in the field are rather unusual. The first manifestation is a disinclination on the part of the animal to move out and graze during the hours of bright daylight. If driven out from the shade, the animal turns away from the sun; blinking is continuous and the eyelids are not more than half opened. Lachrymation is apparently increased and there is a thin yellowish discharge across the face which mats the hair. In more advanced cases the head is held in an elevated position, which gives the impression that the animal is more alert than usual. Possibly the sight is impaired in some of these cases, for the animal lifts its forefeet a little higher than usual. In a small percentage of cases a distinct keratitis develops.

Inflammation of the muzzle is noted; the skin cracks and incrustations appear. There may be a slight discharge from the nostrils. The respiration rate is frequently increased (up to 50 per minute).

Feeding and rumination are usually depressed but the animal does not appear to lose its appetite completely. Oedematous swellings may appear

under the jaw and in the region of the brisket and forelegs. This oedema may be one of the early symptoms, and sometimes it is transient in nature.

Plate 1.

An advanced natural case of yellow-wood poisoning, showing emaciation, photophobia, and evidence of scouring. (The side of the animal is mud-encrusted, due to bogging.)

Urination is much more frequent than usual and occasionally there is an almost continuous dribbling. In affected females, this dribbling causes the animal to hold the tail in an arched position, while the skin below the vulva and along the thighs may be urine-stained and "scalded" in appearance. In males dribbling is, as a rule, not such a marked feature.

Occasionally an affected animal appears to suffer from a form of laminitis. It walks on the heels and the toes turn up, with a growth of horn up to six inches long extending from the toe.

Many graziers recognise a "wet" and a "dry" form of the disease. The "dry" type is characterized by an aggravation of the eye symptoms as the disease progresses, rapid wasting and a relatively early death. In the "wet" type, oedema, which may vary from very slight to very marked, with accumulation of fluid about the lower jaw, the brisket and the legs, develops. Not infrequently both sets of symptoms are seen in the one animal, though

in an outbreak one or other type is usually predominant. A typical case showing the extreme emaciation of a naturally affected animal is shown in Plate 1. A less advanced case of the disease is illustrated in Plate 2.

Plate 2.

A natural case of yellow-wood poisoning, not very advanced, showing wasting, photophobia, and oedema in the region of the throat.

All degrees of the condition are seen in the field. Sometimes when the condition is relatively mild it appears to clear up temporarily, particularly if good rains occur; at other times it runs a fairly rapid course with death usually resulting in 4–8 weeks. Some young cattle partially recover after being affected, but never return to normal and are stunted for the remainder of their lives.

FEEDING TESTS WITH YELLOW-WOOD.

Feeding tests with eleven calves were conducted. The records relating to six of these animals are set out hereunder as typical of the symptoms following ingestion of yellow-wood.

Animal No. 1.

Small Illawarra Shorthorn steer. Approximately 125 lb. live weight. Age 7 months.

Feeding with yellow-wood commenced on April 14. The amount

consumed per day averaged about 7 lb. and consisted of the leaves, which were stripped from the branches. No other food was given. Condition was maintained for the first few days; by the end of a fortnight the appetite was depressed considerably, and the amount of leaves consumed dropped to approximately 4 lb. per day. Attempts were then made to coax the animal to eat a little oaten and lucerne chaff and this was continued for a fortnight. During this period the appetite was depraved: small stones and gravel were licked up from the ground and the bark was chewed from the rails of the fence.

Two weeks after feeding commenced, rapid blinking of the eyelids was noticed, followed a few days later by a bilateral discharge of yellowish material from the inner canthus of the eye. By the end of the first month photophobia was evident, the animal standing in one position with the eyes half closed. Loss of condition was now obvious. Urination became much more frequent and the animal strained a little, often standing for a considerable time with the back arched. Respirations were increased and became shallow and abdominal.

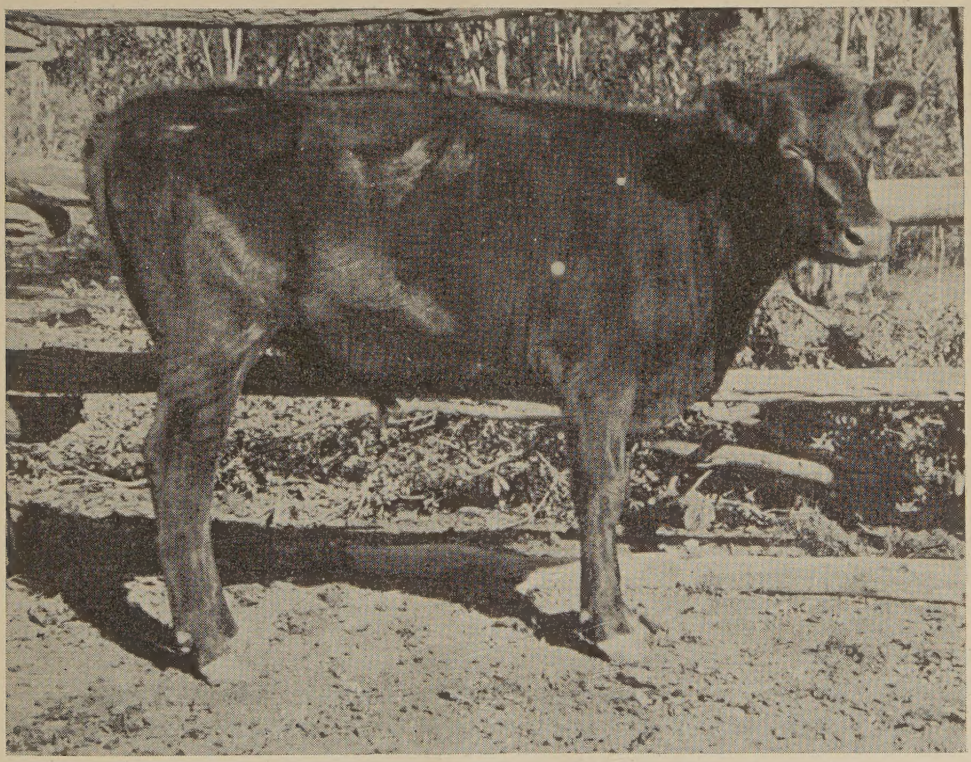

Plate 3.

Experimental animal No. 2, photographed 30 days after commencement of feeding. Note photophobia and eye discharge and the typical stance—head elevated, ears at the alert and back arched.

As the disease advanced, the symptoms noted were gradually aggravated. Frequently, when the beast moved it staggered and fell and only with difficulty regained the normal posture. The skin over the nose dried and cracked. The animal was eventually destroyed 44 days after the experiment commenced, by which time it had consumed 214 lb. of yellow-wood leaves. It was very weak and emaciated when slaughtered.

Animal No. 2.

Illawarra Shorthorn steer. Approximately 180 lb. live weight. Age 10 months.

Feeding commenced on April 14. This animal was a voracious eater, and for approximately six weeks consumed an average of just under 13 lb. of yellow-wood leaves per day. It was then allowed to browse from branches of the tree placed in the yard and no effort was made to measure its daily intake. Blinking and photophobia were in evidence a fortnight after feeding commenced, but these symptoms were not very marked, and the animal generally maintained its appetite. Lucerne was fed occasionally when the appetite appeared to be a little depressed. A month after feeding on yellow-wood commenced it was noticed that the head was being carried in an elevated position and that the animal appeared to be a little more timid than usual when approached. The nose was continually licked—the tongue passing from one nostril to the other—and the skin on the muzzle commenced to crack. The animal is shown at this stage in Plate 3. Urination was much more frequent than usual. A discharge from the eyes dried on the sides of the face, matting the hair. During the seventh week of feeding the general condition became worse and the symptoms aggravated. Respirations had increased and were mainly abdominal. At the time of death, 66 days after feeding commenced, the animal was very emaciated.

Animal No. 3.

Large Illawarra Shorthorn steer. Approximately 280 lb. live weight. Age about 12 months.

For more than two months before entering the trial, this animal was confined and fed on a good ration of oaten and lucerne chaff, maize and bran. It was in excellent condition when the trial commenced.

Feeding on yellow-wood commenced on June 23, the branches of the tree being placed in the yards and the animal allowed to browse at will. No attempt was made to calculate the amount ingested, but the animal ate readily. Rapid blinking was noted 10 days after the trial commenced and a few days later photophobia was evident. Constant licking of and cracking of the skin over the nose were observed and there was considerable discharge from the eyes. Loss of condition was very marked and it was estimated that 15 days after the trial had commenced the animal had lost over 100 lb. in weight. Urination was more frequent and muscular inco-ordination was

observed, the gait being of a lumbering and unsteady nature. If forced to move rapidly the animal lost its balance and fell. It was eventually destroyed 31 days after feeding commenced.

Animal No. 4.

Small Illawarra Shorthorn heifer. Approximately 125 lb. live weight. Age 6 months.

Feeding commenced on June 4 with weighed amounts of yellow-wood leaves, the animal consuming an average of just under 9 lb. per day for the first month.

Blinking was noted during the third week after feeding commenced, and slight scouring occurred at that time. Photophobia was observed about a week after the blinking was first apparent. There was a discharge from the eyes, cracking of the skin over the nose occurred, and the ears were affected with a dry necrosis. Gradual emaciation and frequent urination were noted during the fourth and fifth weeks. The respiration rate had increased considerably. For several days before death the animal refused to consume yellow-wood leaves. An attempt was made to feed it with oaten and lucerne chaff during this period: it ate sparingly and in spite of slight improvement in respect of some of the symptoms remained weak and emaciated. It was destroyed 41 days after the experiment commenced; during the period it had eaten 254 lb. of yellow-wood leaves.

Animal No. 5.

Small Illawarra Shorthorn heifer. Approximately 150 lb. live weight. Age 7 months.

From July 20 the animal was allowed to browse on the leaves from the branches of the tree, which were placed in the yard. It ate readily. Blinking was noted during the third week and photophobia observed a few days later. The respiration rate was increased and there was a slight discharge from the eyes. The animal was destroyed, 19 days after feeding commenced, in a relatively early stage of the disease.

Animal No. 6.

Small Illawarra Shorthorn heifer. Approximately 150 lb. live weight. Age 7 months.

From July 20 this animal, like No. 5, which ran in the same yard, was allowed to browse on the leaves from limbs of the tree freshly cut and placed in the yard. It consumed the plant fairly readily during the first few weeks. During the fourth week the following symptoms were observed:— rate of respiration had increased, blinking was frequent and there was a bilateral discharge from the eyes. Photophobia was noted a few days after blinking had commenced, the animal showing a marked disinclination to face

the sun. Urination became more frequent and was associated with a good deal of straining, the urine being voided in small quantities of about 100–150 ml. at a time. The characteristic attitude of the animal was to stand with its head away from the sun, with the back arched, the legs straddled and the tail half lifted and held to one side. General emaciation was noticeable during the third and fourth weeks after the experiment commenced and by the fifth week muscular inco-ordination was observed. The animal was destroyed 34 days after feeding had commenced.

SUMMARY OF SYMPTOMS IN TEST ANIMALS.

The experimental cattle in all cases ate yellow-wood with relish and there was no difficulty in inducing them to consume considerable quantities per day. For the first two or three weeks condition was in most cases maintained on a yellow-wood diet alone. Usually at the end of this period, symptoms developed, the first one noted being generally blinking of the eyelids. This sometimes increased with the passing of time until movement of the eyelids, especially when the animal was turned to the sun, was at the rate of 40–45 to the minute (normal animals were observed to blink on an average eight times per minute). Soon after increase in blinking was noted, a yellowish discharge appeared which ran over the face, drying in scaly masses. The animals often carried their heads in an elevated manner and appeared to be more alert than usual. Coincident with the appearance of the ocular discharge, photophobia was evident and the animals sought the shade. If forced to move out of the shade, they invariably turned their heads away from the sun.

With the development of photophobia the consumption of the plant decreased and the animals lost condition. Sometimes at this stage a depraved appetite was observed: the animal chewed the bark on the rails of the yard or licked dirt and gravel. An attempt was made to coax some of the animals to eat small quantities of lucerne and oaten chaff. In some of these the appetite gradually returned. One beast, which had consumed considerable quantities of yellow-wood, refused good quality chaff.

The skin of the nose dried and cracked and tended to peel. At first there was a reddening of the shiny surface, followed by exfoliation. Evidently the nose was painful for it was licked continuously, the animal's tongue moving first into one nostril, then into the other.

Increased frequency of urination was observed in several animals though it is not known whether the total amount of urine was increased. One animal was observed to urinate three times within 15 minutes, and when slaughtered after the last act of urination showed approximately 500 ml. of urine in the bladder. Animal No. 6 strained considerably when urinating and assumed a characteristic attitude with the back arched. The tail did not return to the normal position for some time after urination had ceased.

SIMILARITY OF NATURAL AND INDUCED SYMPTOMS.

The disease produced by feeding on yellow-wood leaves differs little from the condition seen in the field and there is no doubt they are one and the same. Under natural conditions, the cattle probably do not consume as much per day as did the experimental animals, due to the fact that the latter were allowed no grazing. It can be assumed, therefore, that in the field the condition tends to become more chronic. This would be sufficient to account for the slight difference in symptoms observed between the two groups.

The most important differences were the presence of oedema about the neck and brisket of the natural cases and the presence of urinary salts about the hindquarters of females and the prepuce of males, features not observed in the experimental animals. It is felt, however, that these variations were due merely to the more chronic nature of the natural disease. The experimental calves showed albuminuria and the consequent loss of protein might conceivably have led to oedema.

LESIONS.

Whether dying from the natural disease, or destroyed after ingestion, under controlled conditions, of considerable quantities of the plant, all animals show some emaciation. The degree, however, differs considerably; in the natural cases it is usually very marked. The alimentary tract may show evidence of catarrh and occasional areas of congestion, though these are not confined to any particular section. Extensive oedema of the rugae and abomasal wall is often seen. This lesion is not necessarily associated with subcutaneous oedematous swellings in the region of the head or brisket. On section the swollen abomasal wall presents a typical whitish gelatinous appearance. Occasionally an oedema of a similar nature, though varying in degree, is observed involving other portions of the alimentary tract and the wall of the urinary bladder.

The organs of the chest cavity show little or no departure from the normal.

The liver, spleen and pancreas show little change as a rule, though in some cases the spleen may appear to be slightly enlarged and softened.

The kidneys exhibit the most marked changes. Though not altered in shape or size, these organs show a peculiar discolouration ranging from greenish-blue to a slate grey. On section, particularly in the more acute type of case, there may be some oedema in the region of the hilus, and there is considerable congestion. The more chronic type suggests the formation of some fibrous tissue, particularly in the cortex. In such cases there may be difficulty in stripping the capsule.

Microscopically the kidneys exhibit a distinct departure from the normal. In the cortex the vessels frequently show congestion, and the glomeruli also are affected. In the capsular space a considerable deposit, probably of protein

material, is evident, suggesting a leakage from the vessels of the glomerulus. The cell walls of the proximal convoluted tubules show evidence of damage, indicated by swelling and the appearance of some detritus in the cavity of the tubule, and the same changes may be seen in the loops of Henle and the collecting tubules. In some advanced cases there is evidence of more extensive damage, indicated by the appearance of fibrous tissue cells between the tubules, though generally this is not a very marked feature. A fine granular brownish material has been observed throughout the deposits in the capsular space, the cells of the tubules, and within the tubular space.

Generally speaking, the condition suggests a subacute to mild chronic parenchymatous nephritis due to an irritant agent.

Marked hypertrophy of the urinary bladder with retention of large volumes of urine is a common feature of chronic cases of the natural disease. In some animals the bladder wall is oedematous, while in others it tends to be indurated and thickened (especially in the neck region), and in these the lining mucosa is inclined to be catarrhal.

No lesions beyond a mild to moderate conjunctivitis have been noted in the eyes in experimental animals, but the behaviour of some of the animals—e.g., the "alert" attitude and the habit of stepping high when moving—suggests that the eyesight is impaired.

BIOCHEMICAL TESTS.

Routine tests to determine the presence of protein were applied to urine samples collected, on post-mortem, from all experimental animals. All samples gave a strong positive reaction; quantitative analysis revealed that the amount rose as high as 0·41 per cent.

Samples collected from the animals before entering the test gave negative results to both the heat and the ring tests.

ACKNOWLEDGEMENT.

Reports submitted by various Departmental officers—particularly Mr. Marshall R. Irving (formerly Departmental Veterinary Officer at Rockhampton) and Mr. W. D. Francis (Botanist, Botanical Section)—in the preliminary stages of the investigation of the disease were of considerable value in the planning and the conduct of the experimental work and have been drawn upon in the preparation of this paper.

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PROTEIN CONTENT AND YIELD OF GRASSES IN THE WET TROPICS AS INFLUENCED BY SEASONAL PRODUCTIVITY, FREQUENCY OF CUTTING AND SPECIES.

By J. L. SCHOFIELD, B.Sc. (Manc.), Agrostologist, Agriculture Branch, Division of Plant Industry.*

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SUMMARY.

1. *Grasses cut at monthly, two-monthly and three-monthly intervals showed (a) minimum values for protein content during the "zenith" period of productivity, (b) a high level of protein content in the period following establishment and during the "low" period of productivity, and (c) transition from high to low protein values and vice versa during the "rapid increase" and "rapid decrease" periods of productivity, i.e., there is a negative correlation between dry-matter yield and protein content.*

2. *The majority of the grasses showed a considerably higher yield of protein under three consecutive monthly cuts than under a single three-monthly cut in the period after establishment. Melinis minutiflora is exceptional in that it yielded 92 per cent. more protein under a system of three-monthly cutting during the first three months than under monthly cutting.*

* Formerly Director, Bureau of Tropical Agriculture.

3. *Under monthly cutting the highest mean protein content for five cuts was shown by Digitaria milanjiana* (14.4 *per cent.*), *Pennisetum clandestinum* (13.7 *per cent.*) *and Urochloa bolbodes* (13.2 *per cent*), *all of which are leafy grasses.*

4. *Three grasses—Brachiaria decumbens, Hyparrhenia aucta and Panicum maximum No.* 1202—*yielded more than* 1,000 *lb. protein per acre per annum under three-monthly cutting. The grasses with the smallest yields were Chloris gayana No.* 6585, *Panicum maximum var. trichoglume and P. maximum var. coloratum.*

5. *The significance of the leaf to stem ratio relative to protein content is emphasized, and it is demonstrated that the leafy grasses show the highest increases in protein content following fertilizer application during the second year.*

6. *An exception to the general pattern of protein yield throughout the year is shown by Hyparrhenia aucta, which differs from all the other grasses in that from July to October the yield of protein rises to a maximum whereas with the other grasses it falls.*

7. *An inverse relationship between fibre and protein content is shown under each cutting system.*

INTRODUCTION.

Investigation of the chemical composition of pastures has received considerable attention in the temperate zone during the past 25 years. In the tropics, however, comparatively little work has been carried out on the subject. This paper deals with the protein content and yield of various grasses in the wet tropics as influenced by productivity period, frequency of cutting, and species. The term protein is used without qualifying adjective throughout the following pages to denote the value obtained by multiplying by 6.25 the total nitrogen as determined by the method of analysis of the American Association of Official Agricultural Chemists (1935). The seasonal productivity of these grasses has been discussed in a previous publication (Schofield, 1944), which should be read in conjunction with the present paper.

REVIEW OF PREVIOUS WORK.

As this paper is concerned with the performance of grasses under tropical conditions, it has been deemed appropriate to consider, first, some work which has been carried out in the tropics, and to follow with a review of several publications referring to results obtained in the temperate zone.

Edwards and Goff (1935), in Hawaii, examined the effect of location, species and season on the chemical composition of five grasses and showed that the "average per cents of protein for all grasses were practically identical for the four locations." Paterson (1938), in Trinidad, selected a two-months' cutting rotation as the most likely to fulfil the average requirements of the three grasses: elephant grass, Guatemala grass and Para grass, and he calculated the yields of crude protein obtained under a high-cut and a low-cut respectively.

Harrison (1942) carried out digestibility trials with a number of green fodder grasses in the West Indies and showed that the figures "do not differ greatly from the results obtained in other countries with material of similar age, grown under similar conditions and rainfall." Cartmill (1944) examined the effect of season on the protein content of three grasses in coastal northern Queensland: the results obtained will be referred to later.

Fagan and Jones (1924), working in Wales, stated that "the leaf portion of the plant is distinctly richer than the stem, and a knowledge of the relative proportions of these parts will prove a fair guide to the nutritive value of a pasture at any period of the year."

Woodman and associates (1926, 1927, 1928, 1929) in England found that the average seasonal crude-protein content of unfertilized pasture under a weekly system of cutting was 24·7 per cent. (dry matter); under a fortnightly cutting system the figure was 23·5 per cent. and with three-weekly cutting a value of 21·1 per cent. was obtained.

Shutt, Hamilton and Selwyn (1928 and 1930) in Canada demonstrated that frequency of cutting and development of white Dutch clover induced a higher protein content in the herbage and that the latter factor was "the more potent of the two"; another factor contributing to the higher protein percentages was the application of sulphate of ammonia and nitrate of soda.

Greenhill (1930) in England showed that herbage from pasture managed under the Intensive System of Grassland Management and of from three to five weeks' growth was closely comparable in respect of chemical composition and dry matter with that obtained by other workers from "pasture cuts" at one- to three-weekly intervals from unmanured pastures.

Richardson and associates (1931) in southern Australia found that the growth stage had a determining influence on the nitrogen and mineral content of a pasture species.

Archibald and associates (1932) in Massachusetts studied the chemical composition of grass fertilized and grazed intensively and showed the marked effect of nitrogen in producing a succulent grass with a relatively large amount of dry matter.

Du Toit and associates (1935) in the Union of South Africa have demonstrated that pure species grown on the same soil and under the same climatic conditions show appreciable differences in mineral and protein content when harvested after definite intervals, e.g., one month.

Taylor (1941) in Natal carried out rotational grazing experiments on Kikuyu grass pasture liberally fertilized with a mixture in which nitrogen in the form of sulphate of ammonia predominated and showed that the protein value often exceeded 25 per cent.

EXPERIMENTAL PROCEDURE.

Certain details of the productivity experiment with which this investigation was linked have been given in a previous publication (Schofield, 1944). At selected cutting periods a sample of herbage for chemical analysis was taken from the bulked material of each of the grasses after cutting and weighing, and the protein content was determined by the standard method.

DATA FOR FIRST 12 MONTHS.

Monthly Cuts.

Protein Content.

Table 1 shows the protein percentages, on a dry-matter basis, of 19 grasses sampled for chemical analysis five times during the first 12 months under a system of monthly cutting. Figure 1 shows in graphical form the seasonal variation in protein content of six of these grasses: *Panicum maximum* vars. *coloratum, trichoglume* and *typica, Brachiaria purpurascens, Paspalum dilatatum* and *Pennisetum clandestinum.*

Table 1.

PROTEIN CONTENT OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).					Mean.
SERIES 1.						
Date of cut	26/4/40	28/5/40	25/6/40	22/10/40	19/2/41	..
Number of cut	1st	2nd	3rd	7th	11th	..
Urochloa bolbodes	14·6	13·2	15·6	14·3	8·1	13·2
Panicum maximum var. *trichoglume* ..	10·9	11·0	13·9	10·5	6·3	10·5
P. maximum No. 1202	14·7	11·5	14·0	9·7	6·7	11·3
P. maximum No. 3783	11·4	10·8	14·3	8·7	7·3	10·5
Digitaria milanjiana	16·7	16·7	18·0	12·5	8·1	14·4
Paspalum dilatatum	16·4	13·6	13·4	11·6	6·9	12·4
Cenchrus ciliaris	14·0	14·3	14·6	10·4	8·2	12·3
SERIES 2.						
Date of cut	6/5/40	5/6/40	5/7/40	1/11/40	30/1/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Hyparrhenia aucta	12·7	13·6	15·5	8·6	5·2	11·1
Cynodon plectostachyum	13·1	14·9	12·8	7·4	8·2	11·3
Panicum maximum var. *coloratum* ..	14·0	15·7	13·3	10·1	5·3	11·7
P. maximum No. 1200	11·1	12·9	13·8	8·2	6·3	10·5
Brachiaria purpurascens	12·8	12·3	12·7	8·8	6·9	10·7
B. decumbens.	12·8	12·0	11·6	8·5	5·1	10·0
Chloris gayana No. 6586	11·2	10·1	10·0	6·9	5·4	8·7
SERIES 3.						
Date of cut	16/5/40	14/6/40	15/7/40	11/11/40	10/2/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Pennisetum clandestinum	18·3	17·9	14·7	8·3	9·1	13·7
Panicum maximum var. *typica* ..	9·5	15·3	11·6	7·5	5·8	9·9
P. maximum No. 3820	12·1	12·1	12·6	8·7	5·7	10·2
Chloris gayana No. 6585	10·4	7·4	8·6	6·3	5·7	7·7
Melinis minutiflora	12·3	13·6	12·4	8·9	7·1	10·9
Mean	13·1	13·1	13·3	9·3	6·7	11·1

The first two cuts (April-May and May-June), made during the period following establishment, corresponded to the end of the wet summer season, the autumn and the commencement of winter conditions. As would be expected,

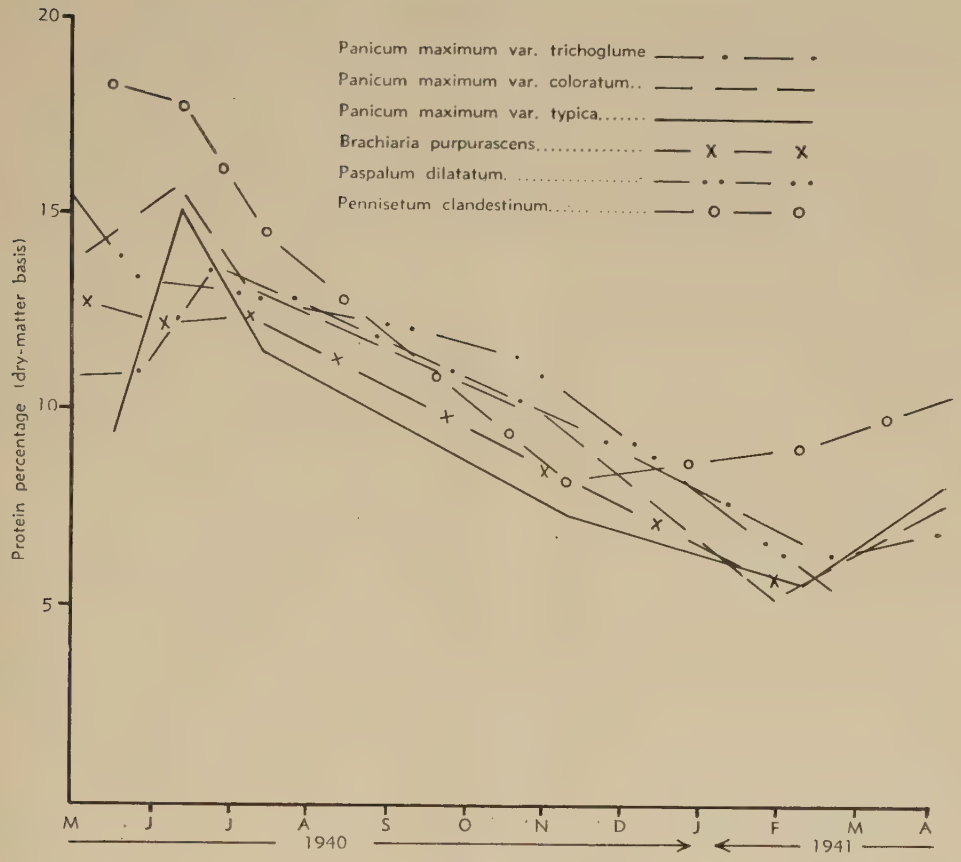

Figure 1.

Showing the seasonal variation in protein content of six grasses during the first 12 months under a system of monthly cutting.

the protein values for all grasses are high throughout this period, the mean being 13·1 per cent. The 3rd cut (June-July) coincides with the commencement of the "low" period of productivity and is characterized by high protein values for all grasses (mean 13.3 per cent.); eight grasses reach their peak at this cut. The 7th cut (October-November) represents the end of the "low" and the beginning of the "rapid increase" period, during which protein values show an appreciable fall, the mean being 9·3 per cent. The 10th cut for series 2 and 3 (January-February), and the 11th cut for series 1 (February) correspond to the "zenith" period, which coincides with a time of great metabolic activity in all grasses and is marked by a continuation of the fall in protein percentage to a much lower level.

The figures given in Table 1 cover five cuts out of a total of 12 for the first year; therefore, the means of the various grasses are valid for comparison of one grass against another over these five cuts only, and do not of course purport to represent the true mean protein composition for the full 12 months.

This pattern of protein content throughout the first 12 months is general for all the grasses examined, but there are points of difference, dependent on species, which deserve comment.

(*a*) An upward trend in protein percentage at the second, as compared with the first cut, is shown by *Cynodon plectostachyum, Melinis minutiflora* and *Panicum maximum* No. 1200 and vars. *coloratum* and *typica*: the increase for the last-named is considerable.

(*b*) Two grasses only—*Cynodon plectostachyum* and *Pennisetum clandestinum*—have a higher protein content at the 10th or 11th cut in January-February than at the 7th cut in October-November. The remaining grasses show decreases, some of which are considerable; e.g., *Urochloa bolbodes* 6·2 per cent. and *Panicum maximum* var. *coloratum* 4·8 per cent. The highest protein percentage at the "zenith" period is shown by *Pennisteum clandestinum.*

(*c*) The magnitude of the difference in protein percentage between the April-May and the January-February cuts varies widely according to the species. It is greatest with *Paspalum dilatatum* (9·5 per cent.), and least with *Panicum maximum* var. *typica* (3·7 per cent.), but the relatively low protein content of the latter grass at the first cut must be considered in this connexion.

(*d*) It is apparent from the data secured that under monthly cutting *Digitaria milanjiana, Pennisetum clandestinum* and *Urochloa bolbodes* may be classified as protein-rich grasses and that five of the remaining grasses—*Panicum maximum* No. 3820 and var. *typica, Brachiaria decumbens,* and *Chloris gayana* Nos. 6585 and 6586—are relatively poor in protein at most stages.

Yield of Protein.

The protein yield at each of the five sampling periods has been calculated from the data for protein percentage and dry-matter yield of herbage (Schofield, 1944) for each of the five cuts and is shown in Table 2. The totals given in the table are, of course, for only five of the 12 cuts made during the first 12 months, and do not represent total yields of protein for the year.

Examination of the totals for the five cuts in conjunction with the dry-matter yield figures in the previous paper shows that, in general, those grasses with the highest dry-matter yield produced the greatest amount of protein per acre. Thus *Brachiaria decumbens,* which throughout the five cuts had a relatively low protein percentage, yielded by far the highest amount of protein because of its high productivity. On the other hand, two protein-rich grasses—*Pennisetum clandestinum* and *Digitaria milanjiana*—produced small total amounts of protein because of their low yield of dry matter. A point of considerable interest is that a negative correlation between protein content and herbage-yield exists at a number of the cuts. Thus for example at the 1st cut $r = -0.5084$ (significant 5 per cent.), at the 2nd cut $r = -0.5774$ (significant 1 per cent.), at the 3rd cut $r = -0.4610$ (significant 5 per cent.), at the

Table 2.

YIELD OF PROTEIN OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

	Yield of Protein in Lb. Per Acre.					Total for 5 Cuts.
Series 1.						
Date of cut	26/4/40	28/5/40	25/6/40	22/10/40	19/2/41	..
Number of cut	1st	2nd	3rd	7th	11th	..
Urochloa bolbodes	141	160	147	64	105	617
Panicum maximum var. *trichoglume* ..	146	140	115	26	62	489
P. maximum No. 1202	145	152	119	52	141	609
P. maximum No. 3783	135	196	103	39	77	550
Digitaria milanjiana	90	105	73	28	78	374
Paspalum dilatatum	96	122	120	42	65	445
Cenchrus ciliaris	113	138	92	30	86	459
Series 2.						
Date of cut	6/5/40	5/6/40	5/7/40	1/11/40	30/1/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Hyparrhenia aucta	63	82	97	116	155	513
Cynodon plectostachyum	150	170	95	45	81	541
Panicum maximum var. *coloratum* ..	188	120	95	23	70	496
P. maximum No. 1200	90	107	108	33	47	385
Brachiaria purpurascens	204	209	119	18	70	620
B. decumbens	330	223	174	86	90	903
Chloris gayana No. 6586	83	113	63	22	41	322
Series 3.						
Date of cut	16/5/40	14/6/40	15/7/40	11/11/40	10/2/41	..
Number of cut	1st	2nd	3rd	7th	10th	..
Pennisetum clandestinum	82	76	165	22	69	414
Panicum maximum var. *typica* ..	215	99	117	37	109	577
P. maximum No. 3820	173	136	76	57	124	566
Chloris gayana No. 6585	161	73	96	18	59	407
Melinis minutiflora	52	113	111	84	81	441
Mean	140	133	110	44	85	512

7th cut r = —0·1894 (not significant) and at the 10th and 11th cuts r = —0·4861 (significant 5 per cent.). The overall correlation coefficient based on the error terms of the analyses, taking cuts as blocks, was equal to —0·4295 (significant 1 per cent.).

Two-monthly Cuts.

Protein Content.

Table 3 shows the protein content of the various grasses at three periods under a system of two-monthly cuts during the first 12 months. The 1st cut (May-June) corresponds to the period following establishment, and comparison of protein figures with those obtained under monthly cutting on the same dates (Table 1) demonstrates that with one exception—*Chloris gayana* No. 6585—all the grasses show considerably lower values: the respective

Table 3.

PROTEIN CONTENT OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF TWO-MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).			Mean for 3 Cuts.
Series 1.				
Date of cut	28/5/40	23/9/40	21/3/41	..
Number of cut	1st	3rd	6th	..
Urochloa bolbodes	10·8	10·3	3·9	8·3
Panicum maximum var. *trichoglume*	6·1	6·0	3·6	5·2
P. maximum No. 1202	8·1	7·1	4·3	6·5
P. maximum No. 3783	6·8	6·8	4·4	6·0
Digitaria milanjiana	11·4	10·3	6·3	9·3
Paspalum dilatatum	10·5	8·3	4·4	7·7
Cenchrus ciliaris	8·8	9·3	5·1	7·7
Series 2.				
Date of cut	5/6/40	1/10/40	30/1/41	..
Number of cut	1st	3rd	5th	..
Hyparrhenia aucta	9·3	7·4	3·6	6·8
Cynodon plectostachyum	10·6	6·3	6·2	7·7
Panicum maximum var. *coloratum*	8·7	7·2	3·8	6·6
P. maximum No. 1200	7·8	6·3	4·3	6·1
Brachiaria purpurascens	7·7	5·3	5·8	6·3
B. decumbens	7·6	5·6	3·7	5·6
Chloris gayana No. 6586	6·1	4·4	3·9	4·8
Series 3.				
Date of cut	14/6/40	11/10/40	10/2/41	..
Number of cut	1st	3rd	5th	..
Pennisetum clandestinum	13·9	8·8	6·7	9·8
Panicum maximum var. *typica*	7·7	7·2	4·2	6·4
P. maximum No. 3820	8·9	7·5	4·4	6·9
Chloris gayana No. 6585	10·3	4·7	3·7	6·2
Melinis minutiflora	10·7	7·1	4·3	7·4
Mean	9·0	7·2	4·6	6·9

means are 13·1 and 9·0 per cent. This is to be expected under a longer cutting rotation, as is shown by the results of numerous workers, e.g., Woodman, Blunt and Stewart (1926) in Britain, and Paterson (1933, 1935) in Trinidad, demonstrated how the protein percentage decreases as the interval between cutting increases.

The 3rd cut (September-October) represents the end of the "low" period of productivity, and at this time all grasses with the exception of *Cenchrus ciliaris* show a reduction in protein (mean 7·2 per cent.). The 5th and 6th cuts (January-March) cover the "zenith" period of productivity, and, as with monthly cutting, the values for protein are much lower than in the period following establishment, although at a greatly reduced level compared with the

more drastic cutting treatment (mean 4·6 per cent.). Actually, the grasses in series 1 should have been analysed at the 5th cut, but due to an oversight the material was discarded after weighing. However, the analyses of these grasses at the 6th cut (21-3-41) are of special interest, because this period represents the mid-point of the wet season and the end of the "zenith" period. Comparison of these figures with those for the remaining grasses in series 2 and 3 cut in late January and early February provides evidence that there is little difference in the protein value of grasses at the commencement and at the end of the "zenith" period of productivity. The highest protein value during the "zenith" period is again recorded by *Pennisetum clandestinum.*

There is a negative correlation between protein content and herbage dry-matter yield at all the cuts examined; at the 1st cut r = —0·4313 (significant 1 per cent. level), at the 3rd cut r = —0.3476 (not significant) and at the 5th and 6th cuts r = —0·4890 (significant 5 per cent. level).

The pattern of protein variability throughout the 12 months under a system of two-monthly cutting is common to most grasses in the experiment, a result in close agreement with findings under the monthly rotation. However, there are important differences between grasses, which can be regarded as characteristic of the species concerned, and some of these will be discussed.

(*a*) The explanation of the apparent exceptional behaviour of *Chloris gayana* No. 6585, which has been commented upon previously, is due to its late-maturing and leafy nature. The fact that this strain at the 1st cut under a two-monthly rotation had a protein content of 10·3 per cent. (strain No. 6586, 6·1 per cent.) whereas on the same date under monthly cutting, but at the 2nd cut, the figure was 7·4 per cent. (strain No. 6586, 10·1 per cent.) is both interesting and important, and demonstrates the value of late maturity combined with leafiness.

(*b*) The majority of grasses at the 3rd cut in September-October (mean 7·2 per cent.), corresponding to the "low" period of productivity, show a tendency to lower values than at the 1st cut (mean 9.0 per cent.). The largest differences are shown by *Chloris gayana* No. 6585, *Pennisetum clandestinum, Cynodon plectostachyum* and *Melinis minutiflora.* It is noteworthy that the grasses in series 1 (cut 23-9-40) show the least difference in protein content between the 1st and the 3rd cuts; this is probably because the date of the 3rd cutting in series 1 is more typical of "low" productivity conditions than the corresponding dates in series 2 and 3, where the influence of the "rapid increase" period of productivity is very evident in the reduced protein level of the grasses.

(*c*) At the 5th or 6th cut, made during the "zenith" period of productivity, all the grasses except *Cynodon plectostachyum, Brachiaria purpurascens* and *Chloris gayana* No. 6586 have a substantially lower content of protein than at the 3rd cut.

(*d*) The protein content of *Paspalum dilatatum, Melinis minutiflora, Chloris gayana* No. 6585, *Urochloa bolbodes* and *Pennisetum clandestinum* is very much lower at the 5th or 6th cut.

(*e*) The data given in Table 3 indicate that under a monthly system of cutting *Pennisetum clandestinum, Digitaria milanjiana, Urochloa bolbodes, Cenchrus ciliaris, Cynodon plectostachyum, Paspalum dilatatum,* and *Melinis minutiflora* may be regarded as high-protein grasses, whereas *Panicum maximum* var. *trichoglume* and *Chloris gayana* No. 6585 are protein-poor.

Yield of Protein.

Table 4 shows the yield of protein obtained at three selected two-monthly cuts. As with monthly cutting, yield of protein depends very largely on yield of dry-matter. Thus the relatively low yields of the protein-rich *Digitaria milanjiana* and *Pennisetum clandestinum* have caused these grasses to produce 370 lb. and 307 lb. of protein per acre only as against 598 lb. per acre from *Urochloa bolbodes,* which is in the same protein-content category.

Table 4.

YIELD OF PROTEIN OF VARIOUS GRASSES AT DIFFERENT DATES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF TWO-MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre.			Total for 3 Cuts.
SERIES 1.				
Date of cut	28/5/40	23/9/40	21/3/41	..
Number of cut	1st	3rd	6th	..
Urochloa bolbodes	382	115	101	598
Panicum maximum var. *trichoglume*	152	75	60	287
P. maximum No. 1202	265	94	178	537
P. maximum No. 3783	321	72	115	508
Digitaria milanjiana	151	62	157	370
Paspalum dilatatum	186	93	106	385
Cenchrus ciliaris	254	52	129	435
SERIES 2.				
Date of cut	5/6/40	1/10/40	30/1/41	..
Number of cut	1st	3rd	5th	..
Hyparrhenia aucta	154	217	211	582
Cynodon plectostachyum	290	126	126	542
Panicum maximum var. *coloratum*	247	66	169	482
P. maximum No. 1200	128	83	72	283
Brachiaria purpurascens	379	66	153	598
B. decumbens	630	203	219	1,052
Chloris gayana No. 6586	146	42	73	261
SERIES 3.				
Date of cut	14/6/40	11/10/40	10/2/41	..
Number of cut	1st	3rd	5th	..
Pennisetum clandestinum	151	69	87	307
Panicum maximum var. *typica*	255	55	151	461
P. maximum No. 3820	361	87	207	655
Chloris gayana No. 6585	344	60	135	539
Melinis minutiflora	225	126	137	488
Mean	264	93	136	493

Similarly, the protein-poor grasses show very marked differences in yield of protein per acre. *Brachiaria decumbens* because of its very high initial productivity easily outyields all the other grasses with 1,052 lb. per acre, while *Panicum maximum* var. *trichoglume* and *Chloris gayana* No. 6586 have the extremely low yields of 287 lb. and 261 lb. protein per acre respectively.

There is a negative correlation between protein content and herbage dry-matter yield in the first 12 months under a system of two-monthly cutting. At the 1st cut r = — 0.4313 (significant 1 per cent.), at the 3rd cut r = — 0·3476 (not significant) and at the 5th and 6th cuts r = — 0·4890 (significant 5 per cent.); the overall correlation coefficient based on the error terms of the analyses is — 0·3736 (significant 5 per cent.).

Three-monthly Cuts.

Protein Content.

The protein contents of the grasses under a system of three-monthly cutting are given in Table 5. Figure 2 contrasts the behaviour of *Pennisetum clandestinum* and *Panicum maximum* var. *typica* under two-monthly and three-monthly cutting, respectively, and illustrates in a general way the trend of protein variation under each system. In comparison with the more frequent

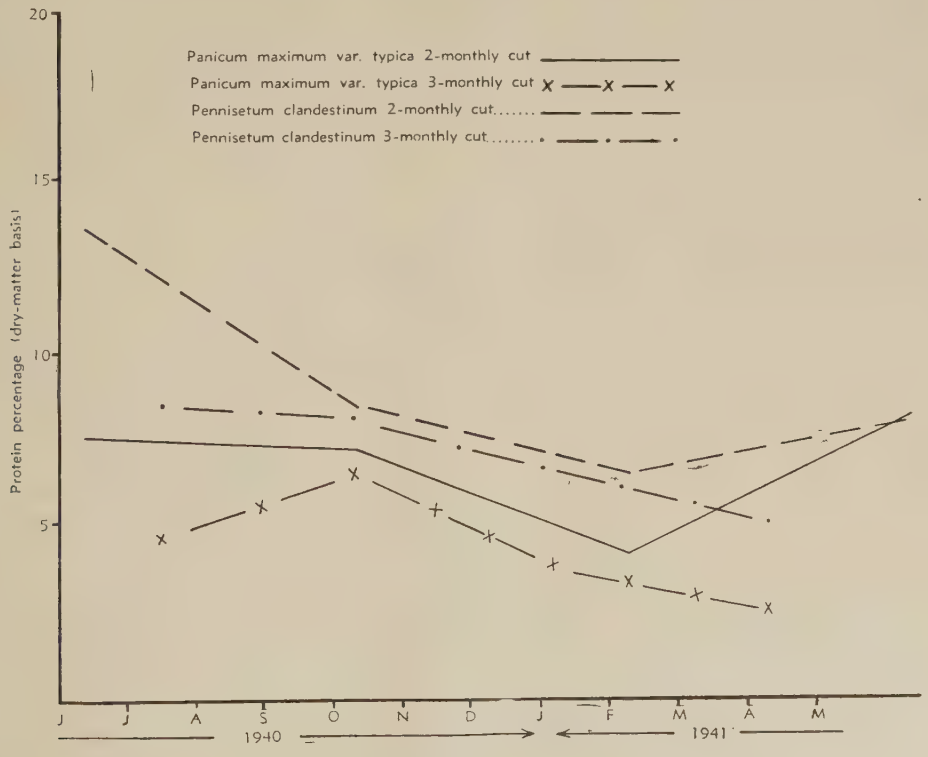

Figure 2.

Contrasting the seasonal variation in protein content of two grasses during the first 12 months under systems of two-monthly and three-monthly cutting, respectively.

Table 5.

PROTEIN CONTENT OF VARIOUS GRASSES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF THREE-MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).				Mean.
SERIES 1.					
Date of cut	25/6/40	23/9/40	20/12/40	21/3/41	..
Period	Period Following Establishment.	Latter Part of "Low" Period.	End of "Rapid Increase" and Commencement of "Zenith" Period.	Latter Part of "Zenith" Period.	
Urochloa bolbodes	7·6	9·3	4·6	3·8	6·3
Panicum maximum var. *trichoglume*	5·7	4·5	4·1	3·5	4·4
P. maximum No. 1202	6·7	6·0	4·5	3·1	5·1
P. maximum No. 3783	5·3	6·1	4·9	2·8	4·8
Digitaria milanjiana	10·1	8·8	5·8	4·0	7·2
Paspalum dilatatum	8·0	7·4	5·6	4·2	6·3
Cenchrus ciliaris	7·4	8·2	6·5	4·0	6·5
SERIES 2.					
Date of cut	5/7/40	1/10/40	31/12/40	31/3/41	..
Hyparrhenia aucta	6·4	6·7	3·3	3·4	4·9
Cynodon plectostachyum	7·2	5·5	5·7	3·6	5·5
Panicum maximum var. *coloratum* ..	7·0	5·9	5·2	3·0	5·3
P. maximum No. 1200	7·1	5·4	..	2·5	5·0
Brachiaria purpurascens	5·7	4·8	5·6	3·2	4·8
B. decumbens	5·4	5·4	4·2	1·9	4·2
Chloris gayana No. 6586	5·0	3·8	5·2	2·7	4·2
SERIES 3.					
Date of cut	15/7/40	11/10/40	10/1/41	10/4/40	..
Pennisetum clandestinum	8·6	8·1	6·8	5·3	7·2
Panicum maximum var. *typica* ..	4·9	6·7	3·9	2·7	4·6
P. maximum No. 3820	5·9	6·2	4·3	2·8	4·8
Chloris gayana No. 6585	4·3	3·5	3·5	3·0	3·6
Melinis minutiflora	7·5	6·1	4·2	3·6	5·3
Mean	6·6	6·2	4·9	3·3	5·3

cutting rotations, three-monthly cutting shows a continuation of the fall in protein values already commented on under the two-monthly cutting system.

The 1st cut (June-July) corresponds to the period following establishment, and comparison of these figures (mean 6·6 per cent.) with those obtained on the same date under monthly cutting (corresponding to the 3rd cut in Table 1—mean 13·3 per cent.) demonstrates that all grasses show a marked reduction in protein content. The 2nd cut (September-October—mean 6·2 per cent.) represents the latter portion of the "low" period of productivity, at which time six grasses show increases, 12 show decreases and one grass remains at the same level compared with the previous cut. The 3rd cut (December-January—mean 4·9 per cent.) corresponds to the end of the "rapid increase"

Table 6.

THREE-MONTHLY CUT—FIRST 12 MONTHS.
Summary of Results—Protein Content.

Grass.	Mean Protein Percentage.	Percentage of Mean.	Significance Table. 1 Per Cent. Level.	Significance Table. 5 Per Cent. Level.
1. *Pennisetum clandestinum*	7·20	136·3	> Nos. 6-18	> Nos. 6-18
2. *Digitaria milanjiana*	7·17	135·9	ditto	ditto
3. *Cenchrus ciliaris*	6·52	123·6	> Nos. 10-18	> Nos. 8-18 (7)
4. *Urochloa bolbodes*	6·32	119·8	> Nos. 14-18	> Nos. 9-18
5. *Paspalum dilatatum*	6·30	119·3	ditto	ditto
6. *Cynodon plectostachyum*	5·50	104·2	> No. 18	> Nos. 16-18
7. *Melinis minutiflora*	5·35	101·3	ditto	> No. 18 (17)
8. *Panicum maximum* var. *coloratum*	5·27	99·9	ditto	> No. 18
9. *P. maximum* No. 1202	5·07	96·1	No significant	ditto
10. *Hyparrhenia aucta*	4·95	93·7	difference	ditto
11. *Brachiaria purpurascens*	4·82	91·4		ditto
12. *Panicum maximum* No. 3820 ..	4·80	90·9		ditto
13. *P. maximum* No. 3783	4·77	90·4		ditto
14. *P. maximum* var. *typica*	4·55	86·2		No significant
15. *P. maximum* var. *trichoglume* ..	4·45	84·3		difference
16. *Brachiaria decumbens*	4·22	80·0		
17. *Chloris gayana* No. 6586	4·17	79·1		
18. *C. gayana* No. 6585	3·57	67·7		
G. Mean	5·28	100·0		
S.E. Mean of 4	·4144	7·85		
Sig. difference P. = 0·05		22·28		
Sig. difference P. = 0·01		29·71		

Season.	Seasonal Mean Composition.	Percentage of Mean	Significance Table 1 Per Cent Level.	Significance Table 5 Per Cent Level.
1. Period following establishment ..	6·59	124·9	> Nos. 3-4	> Nos. 2-4
2. Latter portion of " low " period of productivity	6·28	118·9	ditto	> Nos. 3–4
3. End of " rapid increase " and commencement of " zenith " period of productivity	4·88	92·5	> No. 4	
4. Latter portion of " zenith " period of productivity	3·37	63·8		
G. Mean	5·28	100·0		
S.E. Mean of 18	·1954	3·70		
Sig. difference P. = 0·05		10·50		
Sig. difference P. = 0·01		14·00		

and commencement of the "zenith" period of productivity, and shows with four exceptions a marked decrease in protein content. The 4th cut (March-April—mean 3·3 per cent.), at the later end of the "zenith" period, shows a very marked fall in protein content for all grasses except *Chloris gayana* No. 6585

compared with the 2nd cut. The effect of seasonal productivity on protein content is shown clearly by the mean figures in Table 5 for each of the four cuts corresponding to the four productivity periods.

Because samples from every cut have been analysed and each of the four cuts corresponds more or less to one of the four periods of productivity in the first 12 months, the analysis of variance method has been applied to the protein percentage figures. The F value for grasses is 6·27, which is highly significant, and for seasonal effect F is 57·13, which is very highly significant. A summary of results is given in Table 6.

The chief points of interest in Table 6 are: (1) The grasses with the highest protein percentages include *Pennisetum clandestinum, Digitaria milanjiana, Cenchrus ciliaris, Urochloa bolbodes* and *Paspalum dilatatum.* (2) The analysis of seasonal effect demonstrates that (*a*) protein content in the period following establishment and in the "low" period of productivity is significantly higher at the 1 per cent. level than values in the "rapid increase" and "zenith" periods; (*b*) protein content in the "rapid increase" period is significantly higher at the 1 per cent. level than values in the "zenith" period; (*c*) protein content in the period following establishment is significantly higher at the 5 per cent. level than values in the "low" period of productivity.

The correlation coefficients for protein percentage and herbage dry-matter yield have been calculated for each productivity period during the first 12 months, and the values are given below.

—	Period Following Establishment.	Latter Part of "Low" Period.	End of "Rapid Increase" and Commencement of "Zenith" Period.	Latter Part of "Zenith" Period.
Correlation Coefficient ..	— 0·4843	— 0·2272	— 0·7307	— 0·3944
Degrees of Freedom	16	16	16	16
Significance	5 per cent.	Not significant	1 per cent.	Not significant

The overall correlation coefficient calculated on the error terms of the analyses is —0·3303 (50 D.F.), significant at 2 per cent. level.

Differences between certain species relative to their protein content at various cuts under a system of three-monthly cutting merit comment. The greatest differences in protein at the 1st cut under three-monthly compared with monthly cutting are shown by *Pennisetum clandestinum, Paspalum dilatatum* and *Panicum maximum* No. 1202, and the smallest by *Melinis minutiflora* and *Panicum maximum* var. *typica* and No. 1200. In comparison with two-monthly cutting, the more lenient system at the initial cut showed a substantially lower protein content only with *Chloris gayana* No. 6585 and *Pennisetum clandestinum.*

A comparison of protein content at the 1st and 4th cuts under three-monthly cutting demonstrates that the greatest difference is shown by *Digitaria milanjiana* and the smallest by *Chloris gayana* No. 6585.

Examination of the values of protein content under the three cutting rotations during the "zenith" period of productivity brings out the following points:—

(1) Comparison of monthly and two-monthly cutting shows that the greatest differences occurred with *Urochloa bolbodes, Cenchrus ciliaris* and *Panicum maximum* No. 3783, and the smallest differences with *Brachiaria decumbens, Panicum maximum* No. 3820 and *Brachiaria purpurascens.*

(2) Comparison of two-monthly and three-monthly cutting indicates that the greatest differences occurred with *Cynodon plectostachyum, Brachiaria purpurascens* and *Digitaria milanjiana* and the smallest differences with *Hyparrhenia aucta, Paspalum dilatatum, Urochloa bolbodes* and *Panicum maximum* var. *trichoglume.*

The mean protein figures under three-monthly cutting show that only *Digitaria milanjiana* and *Pennisetum clandestinum* exceeded 7 per cent. and that only *Chloris gayana* No. 6585 fell below 4 per cent.

The highest protein value during the "zenith" period was given by *Pennisetum clandestinum* (5·3 per cent.); the next three grasses were *Paspalum dilatatum* (4·2 per cent.), *Digitaria milanjiana* and *Cenchrus ciliaris* (4·0 per cent.). The lowest protein value was given by *Brachiaria decumbens* (1·9 per cent.), which indicates the very poor quality of this grass in the wet season after three-months' growth under three-monthly cutting.

When the accessibility of protein to ruminants is hampered by a high fibre content there is an appreciable decrease in availability of digestible nutrients. Montgomery White (private communication) has pointed out that there is a marked difference in the coefficients obtained from Rhodes grass at the 0·5 and 1·0 per cent. levels of nitrogen. Such findings serve to emphasize the importance of utilizing protein-rich herbage obtained from suitable strains of gramineous and leguminous species selected on a climatic-regional soil type basis.

Yield of Protein.

Table 7 shows that four grasses—*Brachiaria decumbens, Hyparrhenia aucta, Panicum maximum* No. 1202, and *Melinis minutiflora*—reached a total yield of protein approximating to 1,000 lb. per acre per annum, while *Panicum maximum* var. *coloratum* yielded only 450 lb.

The data have been subjected to the analysis of variance; the F value for varieties is 2·172, which is significant at the 5 per cent. level only, and for seasons F is 19·616, which is very highly significant. The results of these analyses, summarized in Table 8, are of special interest for the following reasons:—(1) It is demonstrated that, in general, grasses with the highest herbage yields produced the highest yields of protein, an exception being *Pennisetum clandestinum,* which gave the lowest yield of green matter (13·6 tons

Table 7.

YIELD OF PROTEIN OF VARIOUS GRASSES DURING THE FIRST 12 MONTHS UNDER A SYSTEM OF THREE-MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre.				Total.
SERIES 1.					
Date of cut	25/6/40	23/9/40	20/12/40	21/3/41	..
Period	Period Following Establishment.	Latter Part of "Low" Period.	End of "Rapid Increase" and Commencement of "Zenith" Period.	Latter Part of "Zenith" Period.	
Urochloa bolbodes	327	150	187	208	872
Panicum maximum var. *trichoglume*	208	84	90	140	522
P. maximum No. 1202	329	137	190	447	1,103
P. maximum No. 3783	302	133	170	240	845
Digitaria milanjiana	265	97	103	329	794
Paspalum dilatatum	254	116	94	147	611
Cenchrus ciliaris	230	66	89	172	557
SERIES 2.					
Date of cut	5/7/40	1/10/40	31/12/40	31/3/41	..
Hyparrhenia aucta	278	365	296	202	1,141
Cynodon plectostachyum	282	156	152	227	817
Panicum maximum var. *coloratum* ..	141	70	137	102	450
P. maximum No. 1200	235	57	..	50	..
Brachiaria purpurascens	360	112	108	92	672
B. decumbens	758	160	231	181	1,330
Chloris gayana No. 6586	234	75	150	129	588
SERIES 3.					
Date of cut	15/7/40	11/10/40	10/1/41	10/4/41	..
Pennisetum clandestinum	249	147	62	189	647
Panicum maximum var. *typica* ..	397	96	174	157	824
P. maximum No. 3820	362	110	175	198	845
Chloris gayana No. 6585	198	64	84	177	523
Melinis minutiflora	529	123	164	179	995
Mean (17 grasses only)*	319	112	139	195	764

**Hyparrhenia aucta* and *Panicum maximum* No. 1200 excluded.

per acre per annum), but due to its high protein content yielded 647 lb. of protein per acre; (2) The significance of herbage productivity in determining protein yield is well shown in the analysis of seasonal effect. The yield during the period following establishment is significantly higher than that during the "zenith," "rapid increase" and "low" periods of productivity at the 1 per cent. level, but yield during the "zenith" period is also significantly higher at the 2 per cent. level than that at the "low" period of productivity. Comparison with Table 6 shows clearly that protein value at the "zenith" and the "low" periods of productivity shows a complete reversal of position due to the preponderant nature of the seasonal factor on herbage yield.

Table 8.

THREE-MONTHLY CUT—FIRST 12 MONTHS.

Summary of Results—Yield of Protein.

Grass.	Total Yield of Protein in Lb. Per Acre.	Percentage of Total Yield (Mean of 18 Grasses).	Significance Table. 5 Per Cent. Level.
1. *Brachiaria decumbens*	1,330	169·4	> Nos. 6-18
2. *Hyparrhenia aucta*	1,141	145·3	> Nos. 11-18
3. *Panicum maximum* No. 1202	1,103	140·4	> Nos. 13-18
4. *Melinis minutiflora*	995	126·7	> Nos. 16-18
5. *Urochloa bolbodes*	872	111·0	No significant
6. *Panicum maximum* No. 3820	845	107·6	difference
7. *P. maximum* No. 3783	845	107·6	
8. *P. maximum* var. *typica*	824	104·9	
9. *Cynodon plectostachyum*	817	104·0	
10. *Digitaria milanjiana*	794	101·1	
11. *Brachiaria purpurascens*	672	85·6	
12. *Pennisetum clandestinum*	647	82·4	
13. *Paspalum dilatatum*	611	77·8	
14. *Chloris gayana* No. 6586	588	74·9	
15. *Cenchrus ciliaris*	557	70·9	
16. *Chloris gayana* No. 6585	523	66·6	
17. *Panicum maximum* var. *trichoglume*	522	66·5	
18. *P. maximum* var. *coloratum*	450	57·3	
Mean of 18 varieties	785·33	100·0	
S.E. total of 4	163·70	20·84	
Sig. difference P. = 0·05	464·61	59·16	

Season.	Mean Yield in Lb. Per Acre.	Percentage of G.M.	1 Per Cent. Level.	2 Per Cent. Level.
1. Period following establishment	316·83	161·4	> Nos. 2, 3 and 4	
2. Latter part of " zenith " period	195·33	99·5	No significant difference	> No. 4
3. End of " rapid increase " and commencement of " zenith " period	147·56	75·2		No significant difference
4. Latter part of " low " period	125·61	64·0		
G.M.	196·33	100·0		
S.E. Mean of 18	19·292	9·83		
Sig. difference P. = 0·02	65·60	33·41		
Sig. difference P. = 0·01	73·00	37·8		

Comparison of Protein Yield under Monthly and Three-monthly Cutting.

The data collected during the first three months of the experiment—corresponding to the period following establishment, when protein values were at their highest—enable a comparison to be made of protein yields of various grasses under monthly and three-monthly cutting systems respectively. Table 9

Table 9.

YIELD OF PROTEIN OF VARIOUS GRASSES DURING THE FIRST THREE CUTS UNDER A SYSTEM OF MONTHLY CUTTING COMPARED WITH THE CORRESPONDING YIELD AT THE FIRST CUT UNDER A SYSTEM OF THREE-MONTHLY CUTTING.

	Yield of Protein in Lb. Per Acre.		
	Sum of First 3 Cuts : Monthly System of Cutting.	First Cut : Three-monthly System.	Difference.
SERIES 1.			
Date of cuts	25/4/40 ; 28/5/40 ; 25/6/40	25/6/40	..
Urochloa bolbodes	448	327	121
Panicum maximum var. *trichoglume*	401	208	193
P. maximum No. 1202	416	329	87
P. maximum No. 3783	434	302	132
Digitaria milanjiana	268	265	3
Paspalum dilatatum	338	254	83
Cenchrus ciliaris	343	230	113
SERIES 2.			
Date of cuts	6/5/40 ; 5/6/40 ; 5/7/40	5/7/40	..
Hyparrhenia aucta	242	278	+ 36
Cynodon plectostachyum	415	282	133
Panicum maximum var. *coloratum*	403	141	262
P. maximum No. 1200	305	235	70
Brachiaria purpurascens	432	360	72
Brachiaria decumbens	727	758	+ 31
Chloris gayana No. 6586	259	234	25
SERIES 3.			
Date of cuts	16/5/40 ; 14/6/40 ; 15/7/40	15/7/40	
Pennisetum clandestinum	323	249	74
Panicum maximum var. *typica*	431	397	34
P. maximum No. 3820	385	362	23
Chloris gayana No. 6585	330	198	132
Melinis minutiflora	276	529	+ 253
Mean	338	313	65

summarizes these results, which reveal marked differences between certain species in their reactions to the two systems. These differences are commented on briefly below.

(1) *Panicum maximum* vars. *coloratum* and *trichoglume* are noteworthy for their high yield of protein during the first three months under monthly compared with three-monthly cutting.

(2) The majority of grasses show a considerably increased yield of protein under three consecutive monthly cuts than under a single three-monthly cut in the period immediately following establishment.

(3) The yield of *Brachiaria purpurascens* for five separate monthly cuts (1st, 2nd, 3rd, 7th and 11th) amounted to 620 lb. protein; from four three-monthly cuts the total was 672 lb., which indicates that frequent cutting during the flush periods of growth would be more satisfactory than allowing this grass to mature for periods of three months throughout the year.

(4) *Melinis minutiflora* is outstanding among the 19 grasses in that it yielded almost twice as much protein from a single cut when three months old than from three monthly cuttings during the same period. Frequent early cutting of this grass should, therefore, be avoided.

(5) Negligible differences in protein yield during the first three months under the two systems of cutting are shown by *Digitaria milanjiana, Hyparrhenia aucta, Brachiaria decumbens, Chloris gayana* No. 6586, *Panicum maximum* var. *typica* and *P. maximum* No. 3820.

DATA FOR SECOND 12 MONTHS.

As stated previously (Schofield, 1944), fertilizer consisting of a mixture of superphosphate and blood, calculated for each grass on the basis of the nutrients removed in the herbage during the first 12 months (estimated from the protein and P_2O_5 figures), was dusted evenly over the whole of each sub-plot immediately after each cut had been made during the second period of 12 months. Due to unfavourable meteorological conditions during the early part of the second year, the effectiveness of the application was delayed until November.

Monthly Cuts.

Protein Content.

Table 10 summarizes the protein percentages for the 13th, 16th, 19th, and 22nd monthly cuts of the 12 grasses which were retained for the second 12 months. Figure 3 shows the marked seasonal variation in protein content which occurs with *Panicum maximum* vars. *coloratum, trichoglume* and *typica, Paspalum dilatatum* and *Pennisetum clandestinum* during the second year. These four cuts correspond approximately to the four productivity periods of the year. The 13th cut (April-May) falls in the "rapid decrease" period, which is characterized by a low protein content for all grasses (mean 8·7 per cent.). The 16th cut (July-August) falls in the early portion of the "low productivity" period, and is marked by a relatively high protein content for all grasses (mean 12·0 per cent.) with the exception of *Melinis minutiflora,* which shows no increase over the preceding period. Increases ranging from

6·9 per cent. with *Panicum maximum* var. *trichoglume* to 1·8 per cent. with *Chloris gayana* No. 6585 were recorded. The 19th cut (October-November) falls at the end of the "low" and the beginning of the "rapid increase" period, a time when fertilizer is becoming effective. The protein figures show a marked decrease for all grasses (mean 8·4 per cent.) with the exception of *Melinis minutiflora*. The 22nd cut (January-February) with a mean of 9·4 per cent. falls in the early portion of the "zenith" period, and the protein figures offer interesting contrasts between the various species. As already observed, the "zenith" period represents a time of great metabolic activity leading to a decrease in protein percentage, but the second 12-months period differs from the first 12 months because of the fertilizer applications made throughout the second year. It has been shown (Schofield, 1944) that two grasses —*Panicum maximum* var. *typica* and *Digitaria milanjiana*—respond markedly in dry-matter yield to fertilizer addition. Apart from yield response, however,

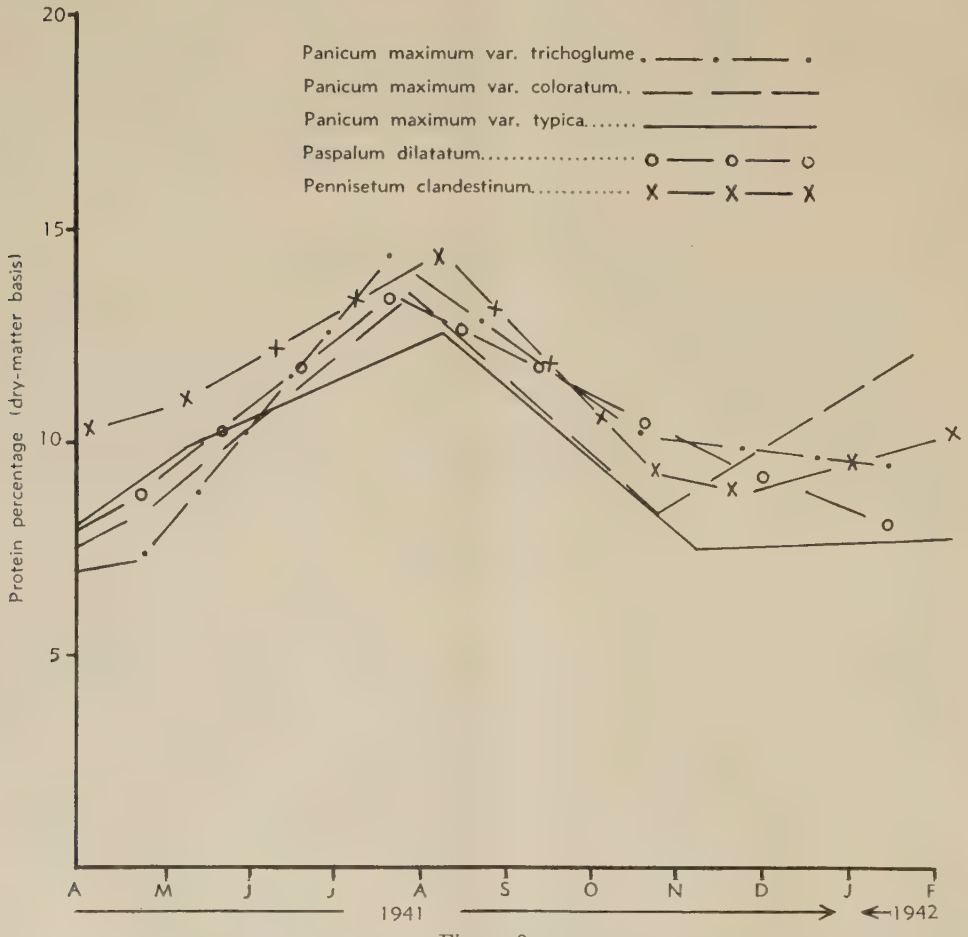

Figure 3.

Showing the seasonal variation in protein content of five grasses during the second 12 months under a system of monthly cutting.

Table 10.

PROTEIN CONTENT OF SELECTED GRASSES AT DIFFERENT DATES DURING THE SECOND 12 MONTHS UNDER A SYSTEM OF MONTHLY CUTTING.

—	Protein Percentage (Dry-matter Basis).				Mean for 4 Cuts.
SERIES 1.					
Date of cut	21/4/41	18/7/41	17/10/41	15/1/42	..
Number of cut	13th	16th	19th	22nd	..
Urochloa bolbodes	9·0	13·6	12·0	10·4	11·2
Panicum maximum var. *trichoglume*	7·3	14·2	10·1	9·6	10·3
Digitaria milanjiana	8·9	11·6	9·1	8·3	9·5
Paspalum dilatatum	8·9	13·4	10·3	8·0	10·1
SERIES 2.					
Date of cut	30/4/41	29/7/41	27/10/41	28/1/42	..
Number of cut	13th	16th	19th	22nd	..
Hyparrhenia aucta	8·6	10·6	6·4	9·0	8·6
Panicum maximum var. *coloratum* ..	8·7	13·4	8·3	12·0	10·6
Brachiaria decumbens	7·6	11·1	6·3	10·5	8·9
Chloris gayana No. 6586	8·4	11·4	6·4	11·7	9·5
SERIES 3.					
Date of cut	9/5/41	8/8/41	6/11/41	4/2/42	..
Number of cut	13th	16th	19th	22nd	..
Pennisetum clandestinum	11·0	14·3	..	10·1	11·8
Panicum maximum var. *typica* ..	9·9	12·7	7·5	7·8	9·5
Chloris gayana No. 6585	7·4	9·2	..	7·7	8·1
Melinis minutiflora	8·4	8·6	8·1	7·7	8·2
Mean	8·7	12·0	8·4	9·4	9·7

it can be expected that fertilizer will have what Konig (1937) described as a *direct* influence on chemical composition. Fagan and Davies (1937) have further shown that two factors—the ratio of stem to leaf and the stage of maturity—have a profound effect on this influence. Therefore, stemmy species cannot be expected to show the improvement in chemical composition as a result of fertilizer application which occurs with leafy grasses, except where the cutting rotation (or grazing management) is so drastic as to effectively curtail the production of stem. Thus it is to be expected that differences in chemical composition between leafy and stemmy grasses will be least under frequent and greatest under lenient cutting or grazing; but always in making such comparisons the pronounced effect of season must be considered. Examination of protein values at the 13th cut ("rapid increase" period), when fertilizer was not effective, with those recorded at the 22nd cut (early portion of the "zenith" period) where fertilizer was active show interesting comparisons between various grasses, but do not reveal any extreme differences.

The marked decrease in protein content shown by *Panicum maximum* var. *typica* is noteworthy, and is explained by the strong negative correlation between herbage yield and crude protein; a yield increase amounting to 694 per

cent. green matter occurred at the 22nd cut over the value at the 13th cut with this variety. The increase of 3·3 per cent. shown by the stemmy strain of *Chloris gayana* (No. 6586) is the result of frequent cutting, which has enabled material much richer in leaf to be harvested than under a longer cutting rotation.

Yield of Protein.

The respective yields of protein for the cuts discussed in the previous section are given in Table 11. These figures demonstrate the marked fall

Table 11.

Yield of Protein of Selected Grasses at Different Dates during the Second 12 Months under a System of Monthly Cutting.

—	Yield of Protein in Lb. Per Acre.				Total for 4 Cuts.
Series 1.					
Date of cut	21/4/41	18/7/41	17/10/41	15/1/42	..
Number of cut	13th	16th	19th	22nd	..
Urochloa bolbodes	20	12	13	49	94
Panicum maximum var. *trichoglume*	21	13	11	28	73
Digitaria milanjiana	36	8	10	32	86
Paspalum dilatatum	30	3	5	14	52
Series 2.					
Date of cut	30/4/41	29/7/41	27/10/41	28/1/42	..
Number of cut	13th	16th	19th	22nd	..
Hyparrhenia aucta	10	14	14	107	145
Panicum maximum var. *coloratum* ..	19	6	7	102	134
Brachiaria decumbens	22	10	8	106	146
Chloris gayana No. 6586	13	5	7	26	51
Series 3.					
Date of cut	9/5/41	8/8/41	6/11/41	4/2/42	..
Number of cut	13th	16th	19th	22nd	..
Pennisetum clandestinum	25	6	..	79	110*
Panicum maximum var. *typica* ..	33	11	18	173	235
Chloris gayana No. 6585	25	6	..	31	62*
Melinis minutiflora	28	10	15	138	191
Mean	24	9	11	74	117

* Sums of three cuts only.

in yield during the second 12 months under a system of monthly cutting, which is most noticeable during the "low" and the beginning of the "rapid increase" periods. One grass only—*Hyparrhenia aucta*—shows an increase during the "low" period compared with the "rapid decrease" period. The outstanding feature is the very marked increase in yield (mean 74 lb. protein per acre) during the "zenith" period shown by all grasses, but particularly by *Panicum maximum* var. *typica* and *Melinis minutiflora*. The lowest yields are given by the two strains of *Chloris gayana* and *Paspalum dilatatum*. It should be noted that *Digitaria milanjiana* did not show a marked

response to fertilizer application until after the date given in Table 11 (15-1-42). Considerable yield increase did occur, however, on 12-2-42 and 17-3-42 (Schofield, 1944), and therefore the yield of protein for this grass rose very steeply in February and March.

Two-monthly Cuts.

Protein Content.

Table 12 summarizes the protein percentages for the 7th, 9th and 11th cuts under two-monthly cutting during the second 12 months. Figure 4 shows in graphical form the seasonal variation in protein content of *Panicum maximum* vars. *coloratum, trichoglume* and *typica, Paspalum dilatatum* and *Pennisetum clandestinum* during this period. The 7th cut (May-June) corresponds approximately to the "rapid decrease" period, and as with the second 12 months under monthly cutting all grasses exhibit a low protein content (mean 7.6 per cent.). The 9th cut (September-October) represents the latter part of the "low" productivity period, corresponding to the time when the

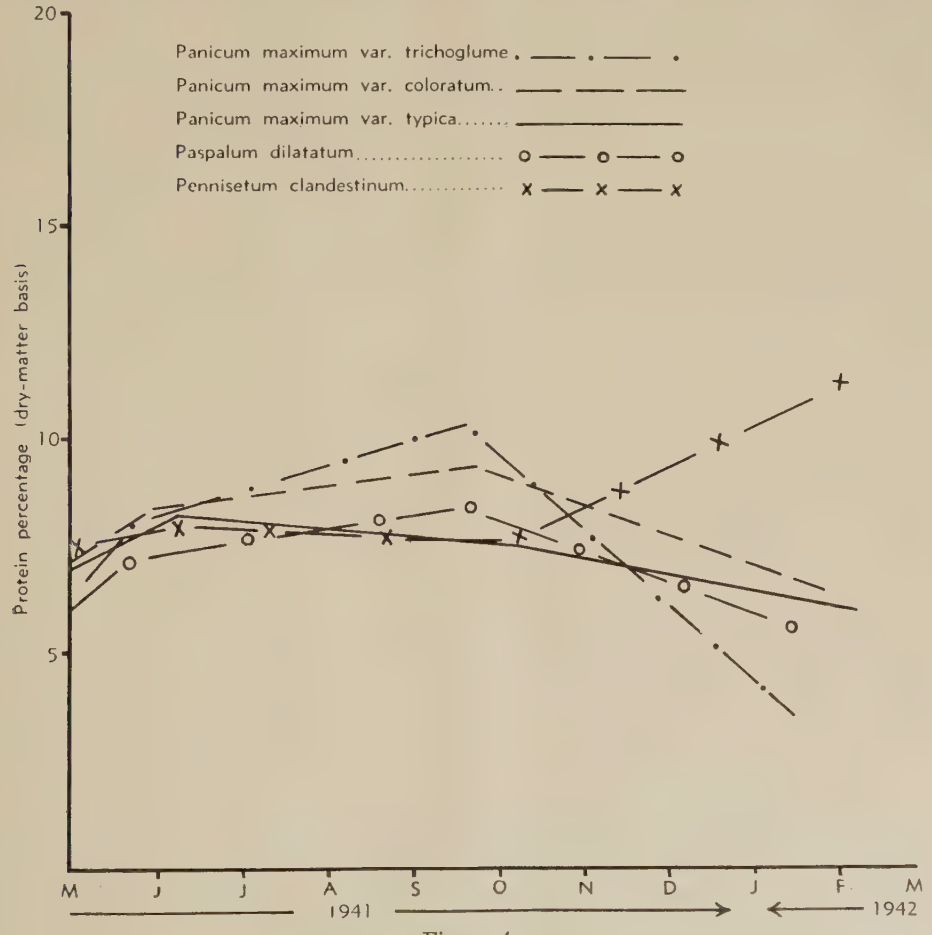

Figure 4.

Showing the seasonal variation in protein content of five grasses during the second 12 months under a system of two-monthly cutting.

Table 12.

PROTEIN CONTENT OF SELECTED GRASSES AT DIFFERENT DATES DURING THE SECOND 12 MONTHS UNDER A TWO-MONTHLY SYSTEM OF CUTTING.

—	Protein Percentage (Dry-matter Basis).			Mean for 3 Cuts.
SERIES 1.				
Date of cut	20/5/41	18/9/41	15/1/42	..
Number of cut	7th	9th	11th	..
Urochloa bolbodes	6·6	11·2	9·6	9·1
Panicum maximum var. *trichoglume*	8·0	10·3	3·7	7·3
Digitaria milanjiana	9·5	7·9	6·6	8·0
Paspalum dilatatum	7·2	8·4	5·8	7·1
SERIES 2.				
Date of cut	30/5/41	26/9/41	28/1/42	..
Number of cut	7th	9th	11th	..
Hyparrhenia aucta	7·5	7·3	6·5	7·1
Panicum maximum var. *coloratum*	8·4	9·3	6·6	8·1
Brachiaria decumbens	7·3	6·5	7·3	7·0
Chloris gayana No. 6586	8·0	7·7	3·1	6·3
SERIES 3.				
Date of cut	9/6/41	7/10/41	5/2/42	..
Number of cut	7th	9th	11th	..
Pennisetum clandestinum	8·0	7·7	11·3	9·0
Panicum maximum var. *typica*	8·2	7·6	6·0	7·3
Chloris gayana No. 6585	5·0	7·8	6·0	6·3
Melinis minutiflora	7·6	5·4	7·8	6·3
Mean	7·6	8·1	6·7	7·5

grasses have passed their peak values for protein and are on the decline due to considerably increased metabolic activity (mean 8·1 per cent.). It is of interest to note that, compared with the 7th cut, three grasses—*Urochloa bolbodes* (4·6 per cent.), *Panicum maximum* var. *trichoglume* (2·3 per cent.), and *Chloris gayana* No. 6585 (2·8 per cent.)—show fairly large increases while *Melinis minutiflora* displays a decrease.

The 11th cut (January-February), with a mean value of 6·7 per cent., corresponds to the early portion of the "zenith" period, and a comparison of protein figures at the 7th and 11th cuts gives useful information on the reaction of the various grasses to fertilizer application (which becomes effective from November onwards) modified by seasonal effect and cutting treatment.

It is noteworthy that the highest increases are shown by leafy grasses—*Urochloa bolbodes* and *Pennisetum clandestinum*—whereas the largest decreases recorded occur with *Panicum maximum* var. *typica* and *Chloris gayana* No. 6586, the former a moderately stemmy and the latter a very stemmy grass (see Table 13). In order to assess the above differences in protein content, account must be taken of the changes in herbage yield which occurred with the various

grasses at these two cuts. The green matter yield of *Urochloa bolbodes* at the 11th cut was 325 per cent. higher than that of the 7th cut, that of *Chloris gayana* 160 per cent., and that of *Panicum maximum* var. *typica* 1189 per cent., whereas that of *Pennisetum clandestinum* was 20 per cent. less. Thus the significant fact which emerges from these comparisons is that *Chloris gayana* strain No. 6586 decreased in protein by 4·9 per cent., although yield increase was a mere 160 per cent., thus denoting a very high proportion of stem to leaf in this grass; whereas the remarkable increase in yield shown by *Panicum maximum* var. *typica* was associated with a decrease in protein of 4·3 per cent., and demonstrates the leafy nature of a large proportion of the herbage produced.

No leaf and stem analyses of grasses in this experiment were carried out at South Johnstone, but subsequently in the Brisbane area samples from four grasses were collected. All four grasses had reached the mature stage of growth, none had been cut or grazed previously in the season and harvesting was undertaken at the beginning of July.

Table 13 shows the percentage composition on a dry-matter basis of the leaf and stem portions and the respective protein contents of four grasses: *Brachiaria brizantha* (closely related to *B. decumbens*), *Chloris gayana, Cynodon plectostachyum* and *Panicum maximum* var. *typica.*

Table 13.

Proportion of Leaf to Stem of Four Grasses cut in the Mature Seeding Stage—early July—together with their respective Protein Contents.

Grass.	Leaf : Stem	Water Free Material.	
		Protein in Leaf.	Protein in Stem.
		%	%
Brachiaria brizantha	1 : 2	6·8	4·0
Chloris gayana	1 : 2·4	8·1	4·2
Cynodon plectostachyum	1 : 2	10·8	4·6
Panicum maximum var. *typica*	1 : 1·1	7·7	5·3

The leaf in the above analyses represents the blade only—that is, the portion above the ligule—and does not include the leaf sheath (see Stapledon, 1924). *Cynodon plectostachyum* and *Brachiaria brizantha* were cut at 2 inches, *Chloris gayana* at 4 inches and *Panicum maximum* var. *typica* at 12 inches above ground level. The above figures demonstrate the very stemmy nature of Rhodes grass and the relatively high proportion of leaf in Guinea grass, even in the very mature stage of growth. The protein composition of the stem of three of the grasses shows little difference, but the Guinea grass stems are decidedly richer in protein. The leaf portion of all the grasses is much higher in protein than the stem, but there are considerable differences between species. African star grass (*Cynodon plectostachyum*) is easily the highest at 10·8 per cent. and *Brachiara brizantha* the lowest at 6·8 per cent.

A further point which indicates the fundamental importance of strain is that the later-maturing leafy strain of Rhodes grass No. 6585 showed a 10 per cent. increase in protein from the 7th to the 11th cut, although herbage yield increased during the same period by 151 per cent.

Yield of Protein.

Table 14 summarizes the yields of protein for the various grasses during the second 12 months under two-monthly cutting. As with monthly cutting, *Hyparrhenia aucta* shows a slightly higher yield at the cut taken towards the end of the "low" period than at that taken during the "rapid decrease" period, although all the other grasses show lower yields, some of which are considerably lower. The outstanding feature again is the markedly higher yield of all grasses—and particularly of *Urochloa bolbodes, Hyparrhenia aucta, Brachiaria decumbens, Panicum maximum* var. *typica* and *Melinis minutiflora*—during the "zenith" period.

Table 14.

YIELD OF PROTEIN OF SELECTED GRASSES DURING THE SECOND 12 MONTHS UNDER A SYSTEM OF TWO-MONTHLY CUTTING.

—	Yield of Protein in Lb. Per Acre			Total for 3 Cuts.
SERIES 1.				
Date of cut	20/5/41	18/9/41	15/1/42	..
Number of cut	7th	9th	11th	..
Urochloa bolbodes	25	23	239	287
Panicum maximum var. *trichoglume*	30	16	62	108
Digitaria milanjiana	79	5	127	211
Paspalum dilatatum	63	9	56	128
SERIES 2.				
Date of cut	30/5/41	26/9/41	28/1/42	..
Hyparrhenia aucta	17	20	217	254
Panicum maximum var. *coloratum*	51	15	149	215
Brachiaria decumbens	56	9	196	261
Chloris gayana No. 6586	20	17	27	64
SERIES 3.				
Date of cut	9/6/41	7/10/41	5/2/42	..
Pennisetum clandestinum	61	7	51	119
Panicum maximum var. *typica*	26	14	163	203
Chloris gayana No. 6585	39	10	117	166
Melinis minutiflora	44	25	169	238
Mean	43	14	131	188

GENERAL PATTERN OF PROTEIN CONTENT UNDER DIFFERENT CUTTING SYSTEMS.

The data given in Tables 12 and 14 and in Figures 1-4 all indicate the operation of a marked seasonal influence, which produces a characteristic pattern of protein content throughout the year, although there are marked differences between various species, and even between strains of the same species, in the level reached.

All three systems of cutting possess these points in common: (1) the minimum values for protein content with all grasses are reached during the "zenith" period of productivity; (2) a high level of protein occurs with all grasses in the period following establishment and during the "low" period of productivity; (3) the "rapid increase" and the "rapid decrease" periods of productivity represent, as far as protein content is concerned, transitional periods from high to low values and vice versa. In effect, the data demonstrate that a negative correlation exists between herbage dry-matter yield and protein content.

Cartmill (1944), working under coastal conditions in northern Queensland, observed a similar rhythm of protein content in the three grasses examined. He pointed out that the highest protein content occurred in the "late-wet" period (June-July), which corresponds to the end of the "rapid decrease" and the beginning of the "low" period of productivity, whereas the lowest protein content was associated with the "pre-wet" period (December-January), which represents the end of the "rapid decrease" and the commencement of the "zenith" period of productivity. Paterson (1933) in Trinidad, has pointed out that with elephant grass "the protein content is lowest when the productivity of the crop is at a maximum."

Summer conditions in coastal northern Queensland bear no resemblance to any climatic conditions in the temperate zone, nor can the winter climate of coastal northern Queensland be compared to the English summer. Nevertheless it is apparent that, under temperate and tropical conditions alike, when herbage production is at a maximum protein content is at a minimum, and as herbage productivity decreases protein content increases (the application of nitrogenous fertilizer, however, increases yield and protein content). The fundamental cause of this negative correlation between dry-matter yield and protein content would appear to be the ratio of leaf to stem, which is conditioned essentially by the influence of meterological factors. It may be stated that the high yields of herbage obtained in the "rapid increase" and "zenith" periods of productivity are due, in large measure, to a higher proportion of stem which depresses the protein content. In fact, mention has already been made (Schofield, 1944) that *free* inflorescence emergence marks a period of *high* "yield" with some grasses, whereas in the "rapid decrease" and "low" periods stem production is at a minimum and the herbage tends to be richer in protein.

The negative correlation which exists between yield and protein content is shown by the following figures in this experiment: *Panicum maximum* var. *coloratum* showed an increase of 435 per cent. during the "zenith" as compared with the "low" period of productivity in the first 12 months under monthly cutting, and the crude protein dropped from 13·3 per cent. (5-7-40) to 5·3 per cent. (30-1-41). In the second 12 months, the increase in productivity rose 41 times (vide Schofield, 1944) and the protein dropped from 13·4 per cent. (29-7-41) when fertilizer was not effective to 12·0 per cent. (28-1-42) when fertilizer effect was strongly in evidence.

With respect to the profound importance of the proportion of leaf to stem relative to crude-protein content, it is of interest to note that Fagan and Davies (1937) quote for *Lolium italicum* a nitrogen value of 3·16 per cent. (leaf) and 1·85 per cent. (stem) at four weeks and 1·74 per cent. (leaf) and 1·01 per cent. (stem) at eight weeks of age; figures in this experiment with a leafy grass, *Pennisetum clandestinum* (including leaf and stem), during the period following establishment in the first year at four and eight weeks respectively were 2·93 per cent., and 2·21 per cent., whereas a stemmy grass, *Chloris gayana* No. 6586 (including leaf and stem) for the same periods gave 1.79 per cent. and 0·98 per cent.

To summarize, the chief points relating to the pattern of protein composition of grasses under different cutting systems are as follows:—

(1) A negative correlation between dry-matter yield and protein content is apparent with all grasses in each of the four periods of seasonal productivity.

(2) The grasses with the highest protein content throughout each 12 months are the leafy grasses, and the lowest protein is found in the stemmy grasses, thereby demonstrating the marked influence of the leaf to stem ratio on protein content.

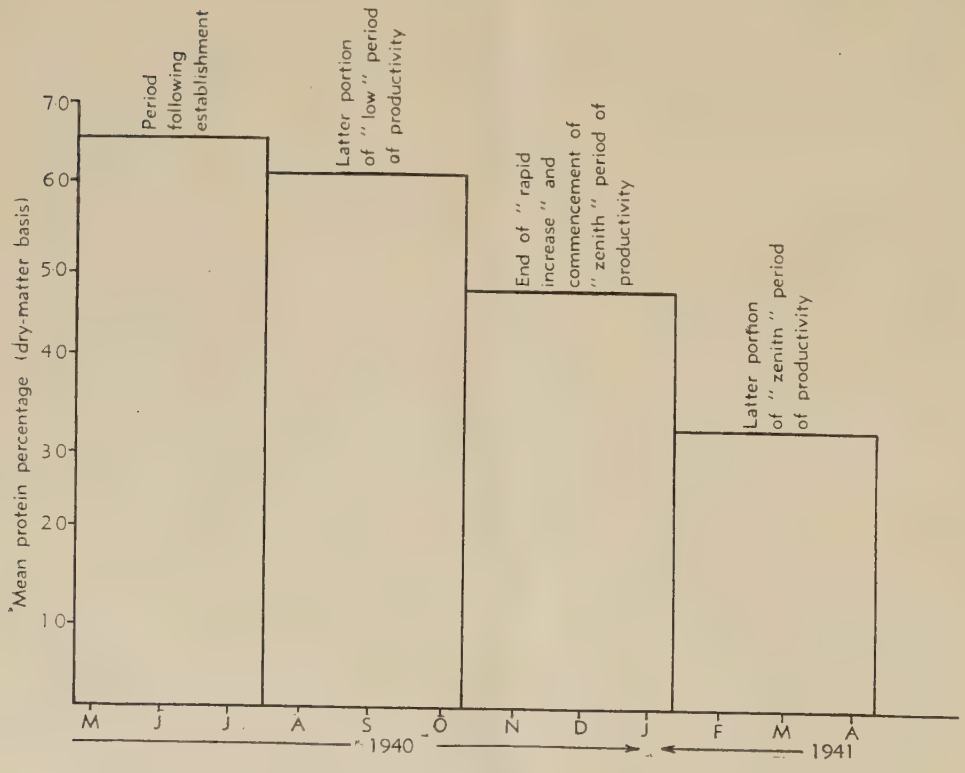

Figure 5.

Showing the seasonal variation in the mean protein percentage of 19 grasses under a system of three-monthly cutting during the first 12 months.

Figure 5 shows in the form of a histogram the characteristic pattern of protein composition during the first 12 months under a system of three-monthly cutting.

AN EXCEPTION TO THE GENERAL PATTERN OF PROTEIN YIELD.

The effect of the meteorological conditions on herbage yield and on protein content throughout the year, under coastal conditions in northern Queensland, involves two contrasting and reciprocal phenomena: summer rainfall conditions promoting herbage yield but limiting protein production, and dry winter influences inhibiting herbage growth but stimulating protein formation. The individual reactions of the various grasses to these seasonal effects have been discussed, and it now remains to determine the general pattern of protein yield, and any exception which may occur among the grasses studied. The figures in Table 7 show the effect of season on protein yield under a system of three-monthly cutting, and Figure 6 demonstrates the marked variation which occurs in yield in each productivity period. The variation applies to 17 out of 19 grasses—*Panicum maximum* No. 1200 was excluded because no yield figure was available for one cut and *Hyparrhenia aucta* because of its exceptional behaviour.

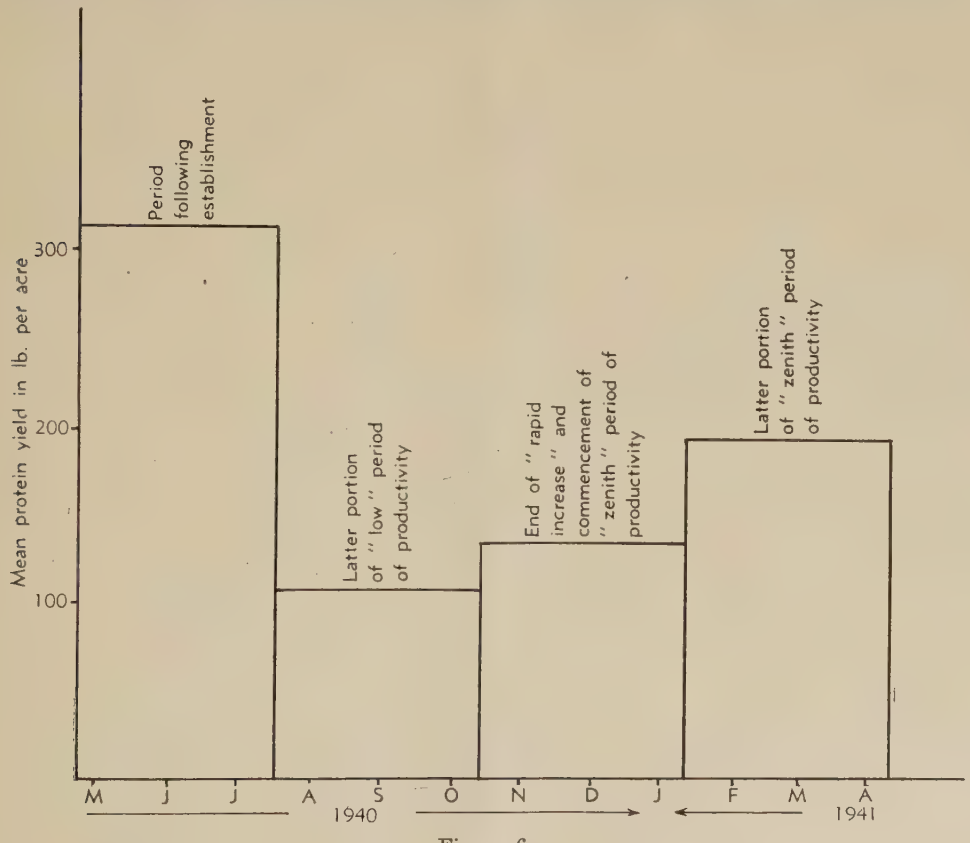

Figure 6.

Showing the seasonal variation in the mean protein yield of 17 grasses under a system of three-monthly cutting during the first 12 months.

This yield pattern is common to each cutting rotation, subject to the differences in herbage yield and protein content resulting under the different cutting systems which have already been examined. In general, it will be observed that the grasses which produced the highest herbage yields also produced the highest yields of protein per acre, but there are a number of exceptions. However, it is not total yield which is now being examined, but the pattern of protein yield, and the figures show that one grass, *Hyparrhenia aucta,* is quite different in this respect. The explanation of this exceptional behaviour is to be found in the different growth periodicity characteristic of this grass (Schofield, 1944). Figure 7 contrasts the yield of protein in pounds per acre from *H. aucta* with that from *Pennisetum clandestinum, Panicum maximum* var. *typica,* and *Cynodon plectostachyum* under three-monthly cutting during the first 12 months. It will be observed that, from July to January, the trend of protein yield from *H. aucta* is practically the reverse of that from *Panicum maximum* var. *typica.* From July to October, the yield of protein with *Hyparrhenia aucta* rises to a maximum, whereas with *Panicum maximum* var. *typica* it falls to a minimum;

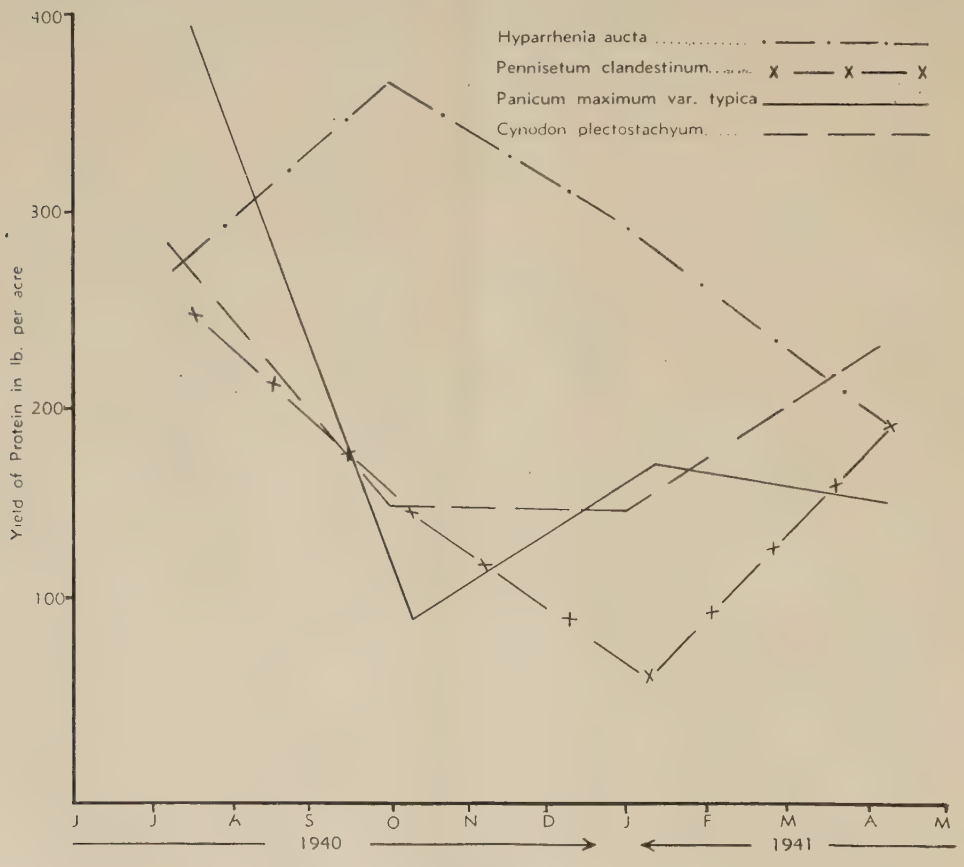

Figure 7.

Contrasting the variation in protein yield of four grasses under a system of three-monthly cutting.

and from October to January the protein yield of *Hyparrhenia aucta* falls and that of *Panicum maximum* var. *typica* increases. *Cynodon plectostachyum*, although it possesses the general pattern of protein yield, differs in not falling below 151 lb. per acre during the "rapid increase" period of productivity, and *Pennisetum clandestinum* is characterized by reaching its minimum value in early January and then increasing rapidly in protein during the "zenith" period.

The exceptional behaviour of *Hyparrhenia aucta* is important, because, if a similar form of crude-protein yield curve could be obtained with a palatable, aggressive, persistent species, it may facilitate solution of a serious problem of animal husbandry in Queensland—the acute seasonal shortage of protein in grass herbage from April until good summer rainfall conditions occur.

RELATIONSHIP BETWEEN PROTEIN AND FIBRE CONTENT.

Table 15 shows the fibre and protein percentages of a number of grasses at various periods under different systems of cutting.

The chief points of interest in these figures may be summarized as follows:—

1. Fibre percentage decreases with increase of intensity in the cutting system. Thus under a system of two-monthly cutting for the period May-June the mean fibre percentage shows an increase of 3·7 per cent. over the corresponding figure obtained with a system of monthly cutting. The mean for a system of three-monthly cutting during the period June-July exceeded that under the monthly system (May-June) by 7·1 per cent.

2. In the "low" period of productivity, when inflorescence emergence is very restricted, the proportion of stem to leaf tends to be at a minimum for most grasses, which results in a low fibre content. Thus for the period of September-October (latter part of "low" period) under a system of two-monthly cutting the mean fibre decreased by 4·5 per cent. compared to the May-June cut; similarly under a system of three-monthly cutting the mean fibre for September-October was 30·5 per cent., whereas in June-July the mean was 32·7 per cent. It is of interest to observe that under a system of two-monthly cutting the three grasses—*Hyparrhenia aucta* and *Chloris gayana* Nos. 6586 and 6585—which possess a fibre percentage exceeding 30 per cent. (September-October) are grasses which show inflorescence emergence at that period.

3. Fibre percentage tends to reach a maximum in the "zenith" period of productivity—the time of maximum inflorescence emergence—and under a system of three-monthly cutting the mean for eight grasses exceeded 40·0 per cent.

4. There is an inverse relationship between the protein and fibre contents of the various grasses under all systems of cutting, a fact which has been observed by many workers, e.g., Evans (1931), and Fagan and Milton (1931) at Aberystwyth, Archibald and associates (1932) in Massachusetts and Du Toit and associates (1935) in South Africa.

DISCUSSION.

The two main conclusions which can be drawn from this investigation refer to:—(1) the effect of seasonal productivity on the protein production

Table 15.

FIBRE AND PROTEIN PERCENTAGES (MOISTURE FREE BASIS) OF A NUMBER OF GRASSES AT VARIOUS PERIODS UNDER DIFFERENT SYSTEMS OF CUTTING.

Grass.	Monthly Cut.				Two-monthly Cut.				Three-monthly Cut.					
	2nd (May-June)		13th (April-May)		1st (May-June)		3rd (Sept.-Oct.)		1st (June-July)		2nd (Sept.-Oct).		4th (March-April).	
	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.	Fibre.	Protein.
SERIES 1.														
Urochloa bolbodes	28·1	13·2	33·0	9·0	33·1	10·8	25·2	10·3	33·8	7·6	25·1	9·3	..	..
Digitaria milanjiana	26·4	16·7	36·1	8·9	31·0	11·4	27·5	10·3	31·5	10·1	28·1	8·8	..	..
Paspalum dilatatum	34·1	13·6	33·5	8·9	33·2	10·5	27·1	8·3	35·1	8·0	28·3	7·4	..	..
SERIES 2.														
Hyparrhenia aucta	31·6	13·6	39·9	8·6	34·6	9·3	36·5	7·4	38·7	6·4	36·4	6·7	44·6	3·4
Panicum maximum var. *coloratum*	29·8	15·7	31·8	8·7	35·2	8·7	26·3	7·2	37·2	7·0	29·4	5·9	45·4	3·0
Brachiaria decumbens ..	28·4	12·0	26·0	7·6	34·0	7·6	28·3	5·6	38·7	5·4	29·3	5·4	39·8	1·9
Chloris gayana No. 6586 ..	34·9	10·1	33·9	8·4	39·2	6·1	34·1	4·4	38·1	5·0	35·0	3·8	40·6	2·7
SERIES 3.														
Pennisetum clandestinum ..	22·6	17·9	30·8	11·0	26·0	13·8	27·5	8·8	34·3	8·6	28·1	8·1	34·6	5·3
Panicum maximum var. *typica*	27·9	15·3	29·9	9·9	36·0	7·7	26·2	7·2	40·6	4·9	28·0	6·7	42·3	2·7
Chloris gayana No. 6585 ..	37·9	7·4	38·5	7·4	37·2	10·3	34·1	4·7	43·5	4·3	35·0	3·5	42·2	3·0
Melinis minutiflora	29·3	13·6	30·8	8·4	32·3	10·7	29·2	7·1	37·8	7·5	32·4	6·1	38·1	3·6
Mean	30·1	13·6	33·1	8·8	33·8	9·7	29·3	7·4	37·2	6·8	30·5	6·5	40·9	3·2

potential of the various grasses, and (2) the significance, under the same soil-climatic conditions, of particular species relative to their efficiency of elaboration of protein throughout the year.

The results demonstrate that the protein content of the grasses follows a marked seasonal pattern, there being a negative correlation between herbage dry-matter yield and protein content. An inverse relationship between fibre and protein content also exists under each system of cutting. There is a serious deficiency of protein throughout the "rapid decrease" and "low" periods of herbage productivity—comprising autumn, winter and early spring—under conditions in coastal northern Queensland. The obvious line of approach towards a solution lies in the introduction of suitable legumes into pastures, and establishment of areas under satisfactory species—representing a phase of legume dominance—including summer-growing types such as species of *Centrosema, Pueraria* and *Stylosanthes* and selected strains of *Cajanus cajan,* and possibly winter-growing legumes. Another line of research is also opened up by the exceptional behaviour of *Hyparrhenia aucta* in this experiment relative to protein yield, namely the use of perennial grasses which possess the characteristic of high-protein yield during the cooler months. Such grasses require to be palatable, aggressive and persistent, but unfortunately *Hyparrhenia aucta* is not palatable.

The marked differences in protein content and in protein yield between the various species is another outstanding feature of the results. It is apparent that, under the same soil-climatic conditions, certain species possess ability to make more effective use than others of soil nutrients in the elaboration of protein. Notable among these protein-rich grasses are the leafy species: *Urochloa bolbodes, Digitaria milanjiana* and *Pennisetum clandestinum.* Of the three, only the last-named represents a species which is sufficiently aggressive and persistent to be of value under certain conditions in coastal Queensland. At the opposite extreme is a number of stemmy grasses which are protein-poor. Table 6 shows that there is no significant difference under three-monthly cutting between 10 of these grasses. The fact that *Chloris gayana* (Rhodes grass) consistently shows the smallest protein content is a feature of the results. Edwards and Goff (1935) in Hawaii found that Rhodes grass contained the lowest protein content of the five grasses examined: they also found that paspalum was slightly higher in protein than Kikuyu grass.

Perhaps the most important conclusion from this experiment, however, is that the same fundamentals of pasture growth—as, for example, the relationship between dry-matter herbage yield and protein content, fibre and protein content, and the influence of seasonal productivity on the relative proportion of leaf to stem—are operative not only in the temperate zone, but also under tropical conditions.

ACKNOWLEDGEMENTS.

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STUDIES ON THE EFFECTS OF TRANSPORT AND STORAGE ON THE BACTERIOLOGICAL QUALITY OF RAW MILK.

Part 2.—The Effect of the Milk Can on the Methylene Blue Reduction Time.

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SUMMARY.

Factors inherent in the milk can have been found to cause a marked fall in the reduction time of raw milk. The effect is accentuated by increased milk temperature and by prolonged transport. Furthermore, such factors result in a greater degree of injury to high quality milks than to low quality milks. No attempt has been made to differentiate between individual can factors.

INTRODUCTION.

In a previous paper (Smythe, 1945) data were presented showing the trends in the methylene blue reduction time of raw milk which follow various conditions of storage time and temperature. Since these data were obtained in the laboratory, where standardized conditions were attainable for the study of such trends, they do not represent entirely the conditions which apply during commercial handling and transport. Under actual transport conditions milk comes under the influence of factors such as contamination from can surfaces, agitation and aeration which may modify quality to a considerable extent. All such factors are intimately bound up with the milk container and for the purposes of this paper are collectively referred to as the "can factor." This paper presents an attempt to study the aggregate effect of these factors, thus affording a more complete interpretation of the effect of handling and transport conditions in Queensland on milk quality as judged by the methylene blue test.

An experiment was performed with the following aims:—

(*a*) To provide a measure of the effect of the can factor on the methylene blue reduction time of raw milk.

(*b*) To learn the extent to which the effect of the can factor may be modified by (1) the quality of the milk transported; (2) the period of holding prior to transport; (3) the duration of transport; (4) milk temperature at commencement of transport; and (5) mean air temperature of transport.

EXPERIMENTAL METHODS.

The effect of the can factor on the reduction of methylene blue has been measured by sampling a large number of milks at pick-up. Samples were drawn from cans of milk into sterile methylene blue test tubes fitted with

rubber stoppers, and these tubes were placed in a basket above the cans in the milk truck. A further sample of each milk was taken at the depots and both series of samples were then brought to the laboratory for testing. In this way a sample of each milk was subjected to much the same conditions of transport as the filled cans, but was removed from further influence of the can container. Such samples served as controls. The difference between the reduction times of tube and can samples has been termed the fall in reduction time and has been taken as resulting from the can factor. It is to be noted that under the conditions of the experiment tube samples were more affected by transport temperature than were the larger bulk lots of milk in the cans. The unavoidable error which resulted will be discussed later.

Air temperatures in the truck were taken throughout the journeys with the thermometer placed in the basket of tubes. Usually such temperatures rose steadily during the mornings and as a result the mean air temperature during transport had to be calculated from the temperatures prevailing during the time each milk was in the truck. Milk temperatures were also taken at pick-up and again at depot.

The pre-transport period—i.e., the time elapsing from the completion of milking until pick-up—was obtained from information given by each

Table 1.

SUMMARY—MEAN VALUES.

No. of Samples.	Fall in Reduction Time. (Hrs.).	Reduction Time of Tube Sample (Control). (Hrs. and Mins.).	Time (Hrs. and Mins.).		Temperature °F.		
			Transport.	Pre-transport.	Milk at Pick-up.	Milk at Depot.	Mean Air Temp. in Truck.
	y	x_1	x_2	x_3	x_4	x_5	x_6
5 ..	0	3 : 27	2 : 40	0 : 44	82·8	83·8	81·5
12 ..	$\frac{1}{4}$	3 : 58	2 : 48	0 : 57	81·4	81·3	78·6
14 ..	$\frac{1}{2}$	4 : 33	2 : 51	1 : 4	81·5	82·2	78·6
19 ..	$\frac{3}{4}$	4 : 9	3 : 2	1 : 9	81·9	81·2	78·7
14 ..	1	4 : 49	3 : 4	0 : 49	82·6	82·2	79·6
16 ..	$1\frac{1}{4}$	4 : 36	3 : 22	0 : 45	85·5	82·9	78·4
12 ..	$1\frac{1}{2}$	4 : 41	3 : 22	0 : 33	85·0	83·3	78·5
4 ..	$1\frac{3}{4}$	4 : 53	3 : 56	0 : 29	82·8	81·0	77·1
5 ..	2	6 : 0	4 : 28	0 : 38	81·4	79·6	76·6
3 ..	$2\frac{1}{4}$	5 : 15	3 : 34	0 : 32	85·0	82·7	77·4
2 ..	$2\frac{1}{2}$	5 : 15	4 : 36	0 : 9	87·4	82·0	75·9
0 ..	$2\frac{3}{4}$	..	..	..	..	..	..
1 ..	3	7 : 30	3 : 30	0 : 24	77·5	79·0	77·4
0 ..	$3\frac{1}{4}$	..	..	..	..	..	..
1 ..	$3\frac{1}{2}$	6 : 30	3 : 48	0 : 6	94·0	80·0	76·0
1 ..	$3\frac{3}{4}$	6 : 15	3 : 54	0 : 30	89·0	84·0	75·8
Mean ...	1·057	4 : 36	3 : 13	49·32 min.	83·131	82·028	78·554
S.E. of mean	±·068	±7·24 min.	±5·48 min.	±3·39 min.	±·385	±·281	±·259

producer. As producers were not always waiting with their milk and as some who were waiting may not have been accurate with the information they supplied, the data in this respect had to be treated with caution. The duration of transport was taken as the period from pick-up until commencing the methylene blue test. On no occasion were samples iced. As in previous experiments the technique of Wilson (1935) was used for methylene blue testing.

EXPERIMENTAL DATA.

The fall in reduction time from the tube sample to the can sample has been taken as an index of the effect of the can factor. In no instance was a negative fall observed, while in only 5 cases out of a total of 109 was the fall found to be zero. Thus, in such instances, no deterioration in reduction time can be attributed to the cans. In order to express the great bulk of results obtained a summary of mean values has been set out as a frequency table in Table 1. In this summary a class range of $\frac{1}{4}$-hour fall in reduction time has been used.

In order to find whether the observed fall in reduction time was related to any of the six variables measured the data obtained for each sample have been taken separately and a statistical analysis performed using the method of partial regression.

The following variables were measured:—

y = fall in reduction time from tube to can sample.
x_1 = reduction time of tube sample (control).
x_2 = transport time.
x_3 = pre-transport period.
x_4 = milk temperature at pick-up.
x_5 = milk temperature at depot.
x_6 = mean air temperature of transport.

A partial regression equation of the following type was fitted:—

$$y - \bar{y} = b_1(x_1 - \bar{x}_1) + b_2(x_2 - \bar{x}_2) + b_3(x_3 - \bar{x}_3) + b_4(x_4 - \bar{x}_4) + b_5(x_5 - \bar{x}_5) + b_6(x_6 - \bar{x}_6)$$

The analysis of variance is given in Table 2, and a summary of regression coefficients with corresponding "t" values is given in Table 3.

Table 2.

ANALYSIS OF VARIANCE.

Source of Variation.	D.F.	Sum of Squares.	Mean Square.
Regression	6	457·67	76·28
Residual	102	411·60	4·035
Total	108	869·27	..

F for regression = 18·9, which is very highly significant.

Table 3.

SUMMARY.

Regression Coefficient.	"t"
$b_1 = \cdot 233 \pm \cdot 040$	5·82
$b_2 = \cdot 764 \pm \cdot 280$	2·73
$b_3 = -\cdot 560 \pm \cdot 375$	1·49
$b_4 = \cdot 324 \pm \cdot 068$	4·75
$b_5 = -\cdot 011 \pm \cdot 115$	<1
$b_6 = -\cdot 222 \pm \cdot 098$	2·26

The interpretation of partial regression coefficients is such that the significance tested is actually that of the additional amount of variation in fall in reduction time accounted for by the variable under consideration over and above that accounted for by the remaining variables. Thus, in the case of variable x_5 (milk temperature at depot), all that may be said is that the fit of the regression line ignoring this variable is not significantly worse than the fit of the regression line on all six variables. In other words, the data supply evidence that any effect on the reduction time resulting from the temperature of the milk at the depot is adequately represented by the effects of the remaining variables.

Regression coefficients b_3 and b_5 are not significant. Coefficients b_3 and b_6 are negative, indicating that the fall in reduction time is less for higher values of variables x_3 and x_6. As noted previously, the data for x_3 were not trustworthy, and as the value is not significant the result may be attributed to this feature.

Since the reliability of the data for x_3 possibly affects the other coefficients, a second analysis was carried out omitting this variable together with x_5, which was found insignificant in the first analysis. The results of this second analysis are set out in Tables 4 and 5.

Table 4.

SECOND ANALYSIS OF VARIANCE.

Source of Variation.	D.F.	Sum of Squares.	Mean Square.
Regression	4	448·67	112·17
Residual	104	420·60	4·044
Total	108	869·27	..

F for regression = 27·7, which is very highly significant.

Coefficients b_1, b_2 and b_4 are significant; b_6 is negative and significant at the 5 per cent. level. The negative value of this coefficient would indicate that, when other factors are constant, the fall in reduction time is greater when the mean air temperature of transport is lower. Such a result is anomalous.

Table 5.

SUMMARY.

Regression Coefficient.	"t"
$b_1 = \cdot 244 \pm \cdot 039$	6·18
$b_2 = \cdot 910 \pm \cdot 245$	3·72
$b_4 = \cdot 344 \pm \cdot 050$	6·81
$b_6 = -\cdot 188 \pm \cdot 089$	2·12

The explanation of this result obviously lies in the fact that the smaller bulk of the tube samples was more affected by air temperature in the truck than was the larger bulk of milk in the cans. In every instance the milk in cans was higher in temperature than the truck atmosphere, with the result that a fall in milk temperature was inevitable. The tubes of milk quickly fell to air temperature, inducing a slightly prolonged reduction time. The lower the air temperature, the more prolonged would the reduction time become. This lengthening would be reflected not only as a prolonged control value, but as an increased fall in reduction time from the tube to the can samples. The only way to overcome this defect in technique would have been to immerse the tube samples in the cans of milk, thus producing equality in the temperature trends of both samples and bulk. As this would have been most undesirable for many reasons, the error had to be accepted. Unfortunately, however, this error was very far reaching and no doubt caused a general increase in all observed falls in reduction time.

DISCUSSION.

The results obtained show that factors inherent in the milk can may be responsible for a considerable fall in the methylene blue reduction time of raw milk quite apart from the fall resulting from time and temperature of storage. A mean fall in reduction time of 1 hour 3 minutes was observed with 109 milks stored and transported under actual commercial conditions when the mean period of transport from pick-up to testing was 3 hours 13 minutes. This fall is independent of the direct effect of temperature and time, but is influenced by the effect of these two factors on the can factor. It is suggested that this fall in reduction time is the result, either directly or indirectly, of improperly sterilized can surfaces.

Observations made on the condition of cans returned to farmers from Brisbane milk depots suggest that bacterial contamination from cans is probably the greatest contributing agency to the can factor. It is obvious that organisms closely associated with a can surface which has been improperly cleansed and sterilized will provide constant contamination of the contained milk when conditions for bacterial growth are favourable. Particularly would this be true when minute pitting of the can surfaces harbours sporing bacilli, incapable of sterilization under farm conditions. The effect of aeration and agitation cannot, however, be completely ignored. Following the work of

Wilson (1935), Davis and Newland (1944) and Davis *et al.* (1945) it would appear that agitation and aeration may considerably modify the quality of milk samples. It is probable that similar phenomena occur in the case of milk in cans and particularly in partly filled cans.

The effect of the can factor may, however, be influenced to a great extent by a number of contributory factors. As would be expected, particularly in the light of the results previously obtained (Smythe, 1945), temperature and time exert a marked influence. Within the temperature ranges prevailing at the time of experiment the effect of milk temperature was found to be greater than that of time. The temperature of the milk at pick-up was found to be directly related to the fall in reduction time. This places emphasis on the need for rapid cooling of milk on the farm. No relation could be found between the milk temperature at the depot and the fall in reduction time. Such a result would be expected to follow the levelling-out of milk temperatures during transport.

The duration of transport has been shown to affect the fall in reduction time in a significant manner. The transport period has been taken as extending from the time of pick-up of the milk until commencing the methylene blue tests. Actually this period was longer (approximately 1 hour) than the true time of transport, that is, from pick-up to tipping, since milks were sampled at tipping and brought to the laboratory for testing. Data concerning the pre-transport period from completion of milking to pick-up must be regarded as being largely unreliable, and as a consequence no importance was attached to them.

Probably the most interesting feature of the results is the marked positive relation between the quality of the milk, as shown by the reduction time of the tube sample which is taken as a control, and the fall in reduction time. Other factors being constant, the fall in reduction time is much greater when milk quality is high. This result is a parallel to that obtained in the previous work (Smythe, 1945) in respect to temperature and time, but the effect is even more marked in this instance. No further explanation can be offered than was tendered then, namely, that poor quality milks allow comparatively less scope for bacterial growth and consequent reduction by virtue of the heavy bacterial populations they already carry than do milks of better quality.

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PRELIMINARY GRAZING TRIALS WITH *STYLOSANTHES GUIANENSIS*-GRASS MIXTURES

By J. L. SCHOFIELD, B.Sc. (Manc.), Agrostologist, Agriculture Branch, Division of Plant Industry.*

SUMMARY.

Grazing trials with Stylosanthes guianensis in admixture with various grasses showed that the legume persisted satisfactorily in association with Para grass and with Kikuyu grass, but was suppressed by various other grasses.

INTRODUCTION.

The initial trials with a number of legumes at the Bureau of Tropical Agriculture in coastal northern Queensland were described in a previous paper (Schofield, 1941). These trials showed that the following tropical exotic perennial legumes were worthy of further study for pasture purposes: *Calopogonium mucunoides* (calopo), *Centrosema pubescens* (centro), *Pueraria phaseoloides* (puero) and *Stylosanthes guianensis* (stylo). Grazing trials with each of these legumes, alone and in combination with one another, were subsequently conducted, and a further grazing trial was carried out with stylo in association with each of eight perennial grasses. The purpose of the last-named experiment was to obtain information on the effect of the grazing animal and of its manurial residues on stylo in combination with a grass. The grasses employed were *Brachiaria decumbens* Stapf, *B. brizantha* Stapf, *B. purpurascens* Raddi (Para grass), *Panicum maximum* var. *typica* (common Guinea grass), *P. maximum* var. *coloratum* C. T. White (purple-topped Guinea grass), *Pennisetum clandestinum* Hochst. (Kikuyu grass), *Melinis minutiflora* Beauv. (molasses grass), and *Paspalum dilatatum* Poir. (paspalum).

A description of the experimental area at the Bureau, including soil and climatic conditions, has appeared in a previous paper (Schofield, 1944).

TECHNIQUE.

Layout.

The layout was an 8 × 2 randomized block, with plots 40 feet by 10 feet. A pathway 6 feet wide separated the two blocks, and adjacent plots were divided by a pathway 4 feet wide.

Soil Preparation.

The experimental area had been under sugar cane for 15 years and when ploughed in October, 1939, a third ratoon crop had just been harvested. Lime was applied in early November to increase the pH of 4·6 (determinations made in June, 1940, gave a mean pH of 6·4), and a basal fertilizer dressing consisting of 1½ cwt. superphosphate, ½ cwt. bonedust, ¼ cwt. blood, ¼ cwt. sulphate of ammonia, and ¼ cwt. potassium sulphate per acre was harrowed in during December.

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Seed Scarification.

Prior to planting, the seed of stylo was scarified by grinding with sand. Previous work with this legume had indicated that seed scarification is necessary to ensure uniform early germination. Table 1, which is prepared from the results of germination tests carried out in the Seed Testing Laboratory of the Department of Agriculture and Stock, indicates the improvement in germination effected by scarification of stylo seed.

Table 1.

SHOWING THE EFFECT OF SCARIFICATION ON THE GERMINATION OF SEED OF *Stylosanthes guianensis*

Treatment.	Germination Temperature deg. C.	Germination Percentage.			Percentage of Hard Seed.
		2 Days.	6 Days.	13 Days.	
Natural	32	Nil	6	13	82
Hull covering removed by hand	32	17	31	33	52
Sandpapered	32	50	82	84	11
Natural	20	Nil	10	13	79
Sandpapered	20	Nil	27	41	40
Natural	20 (night); 32 (day)	4	14	20	68
Sandpapered	20 (night); 32 (day)	32	72	72	20

Planting.

The grasses were planted in mid-January in rows 2 feet apart, with the tillers (or seeds, in the case of molasses grass and paspalum) spaced 2 feet apart. Seed of stylo was sown in the inter-rows midway between the grasses. Satisfactory establishment was obtained in all plots, except that both molasses grass and paspalum had to be reseeded. Inter-row cultivation was carried out until the commencement of the wet season in order to control early weed growth.

Table 2.

SHOWING COMMENCING DATES OF THE 2-4-DAY GRAZING PERIODS AND RAINFALL BETWEEN GRAZINGS

Date.	Rainfall (Inches).
July 4, 1940	99·46
August 9, 1940	1·50
September 29, 1940	2·36
January 6, 1941	10·00
February, 10, 1941	28·83
March 5, 1941	21·01
March 26, 1941	16·08
June 4, 1941	72·12
July 30, 1941	2·38
October 14, 1941	2·64
November 20, 1941	6·19
December 31, 1941	2·79
February 16, 1942	13·61

Grazing.

The plots were first grazed on July 4, 1940, after a period of establishment of 5½ months. Thereafter, the period between grazings was determined by the growth of the herbage. Initially, an electric fence with movable wires was used and each plot was grazed separately. Later, however, the animals were allowed access to all plots: this enabled observations to be made on grazing preferences. Table 2 shows that grazing was carried out on 12 occasions after the initial stocking, the final period being in February, 1942. Notes on the development of each pasture species in the individual plots were made before and after grazing. The plots were heavily stocked, and following each grazing the dung on each plot was spread evenly. From time to time the plots were mowed after grazing to control the ungrazed coarse stemmy material.

Sampling.

Initially, a quadrat 3 feet × 1½ feet was used for sampling herbage and three random cuts were taken per plot. Later, a quadrat 1½ feet × 1½ feet was employed, and two random cuts were made per plot. The cut material was subjected to botanical analysis in the laboratory.

BOTANICAL COMPOSITION.

Botanical analyses of samples taken from six of the eight associations, and comprising five grazing periods, were carried out. The respective percentage contributions to total yield made by stylo are given in Table 3. The results can be considered merely as an indication of the general trend of fluctuation of stylo in each association under grazing, subject to the limitations imposed by restricted sampling from duplicate plots. Nevertheless, the differences between the various treatments became so pronounced during late 1941 and early 1942, and field observations amply confirmed the botanical analyses, that these data provide strong evidence of the ability of stylo to persist in association with two grasses—Para grass and Kikuyu grass; in such associations it is able to withstand heavy grazing and severe plant competition.

Table 3.

SHOWING THE PERCENTAGE CONTRIBUTION TO TOTAL YIELD BY STYLO AT FIVE GRAZING PERIODS.

Period of Growth before Grazing.	*Brachiaria decumbens.*	*Brachiaria brizantha.*	*Brachiaria purpurascens.*	*Panicum maximum* var. *typica.*	*Panicum maximum* var. *coloratum.*	*Pennisetum clandestinum.*
Jan. 20 to July 4, 1940 (Period of establishment)	57	57	42	39	67	24
July 6 to Aug. 9, 1940..	38	48	39	55	50	32
Aug. 2 to Oct. 14, 1941	5	8	43	13	38	50
Nov. 22 to Dec. 31, 1941	3	6	24	9	4	25
Jan. 3 to Feb. 16, 1942	1	6	42	5	11	41

Figures for the molasses grass and paspalum plots are not given because, as already stated, these grasses were late in establishment and no satisfactory comparison could be made on this account. However, the legume developed well, and at the end of the experiment there were numerous seedlings of stylo throughout the plots of these grasses.

The results given in Table 3 are of considerable interest for two reasons: (1) they indicate clearly one of the main limiting factors to the use of stylo in association with certain pasture components, namely the shade factor, and (2) satisfactory self-regeneration of stylo occurs when the associated species allows ample light to reach the legume and when management is such that heavy grazing is avoided during the flowering-seeding period.

FIELD OBSERVATIONS ON GRAZING.

Stylosanthes guianensis (Stylo).

During the early grazing periods of the experiment it was clearly demonstrated that stylo was not grazed by the stock, which had no previous experience with this legume. To accustom the animals to stylo they were placed on a small block of the pure legume for two days. During the first day practically no stylo was eaten but, gradually, the stock commenced to graze, and later took it readily. Once the animals had acquired a taste for stylo, no further serious difficulty was encountered, although there would appear to be a period—when the plant is producing new leaf—during which the foliage is relatively unpalatable. On June 5, 1941, stylo was readily grazed in all pots. During the period July 30-August 1 very little of the legume was taken, but on the two following days it was grazed well in all plots.

In October and November, stylo was not grazed readily and it is of interest to note that this corresponds to a period when new leaf was being developed. During January, 1942, stylo was lightly grazed. In February, it was grazed well in the following plots: Para grass, common Guinea grass, Kikuyu grass and molasses grass. Thus, as the season advanced the relative palatability of stylo would appear to improve progressively.

Stylo-Brachiaria decumbens.

Plate 1 illustrates the associated growth of stylo and *Brachiaria decumbens* prior to the first grazing in July, 1940. By comparison with the other grasses *B. decumbens* was never well grazed. The stock on no occasion grazed the stems but confined themselves to the flag, particularly the deep green flag. The best grazing occurred in February, 1942. The tangled mass of ungrazed stems on these plots necessitated frequent mowing after grazing to prevent the growth becoming too rank.

The dense growth habit of *B. decumbens* effectively cut off light from the associated legume and the stylo population diminished rapidly. The botanical analyses listed in Table 3 show that by February, 1942, only a few stylo plants remained.

Plate 1.

Stylo in association with *Brachiaria decumbens*.

Stylo-Brachiaria brizantha.

The grass was well grazed, occasionally down to as low as 3 inches above ground level. Small amounts of stalky material remained after grazing. This grass by reason of its growth habit inhibited the development of the associated stylo seedlings, but not so severely as *B. decumbens*.

Stylo-Brachiaria purpurascens.

The grass was heavily grazed throughout the period of the experiment. Its open decumbent habit allowed ample light to reach the associated legume. As a result, the stylo plants thrived, flowered and set seed freely, and later self-regeneration was general throughout the plots. The botanical analyses indicate that the legume persisted throughout the two years of the trial.

Stylo-Panicum maximum var. typica.

The grass was heavily grazed throughout, all leaf being taken, leaving stems approximately 1 foot in height. Two factors are responsible for the small number of stylo plants which survived in these plots. One has already been mentioned, namely the shade factor. The second resulted from the stooling habit of Guinea grass, which caused a considerable amount of trampling by grazing stock on the stylo plants situated between the stools.

Stylo-Panicum maximum var. coloratum.

This variety is very palatable and all available leaf was taken readily during every grazing period. Similar factors to those in the common Guinea

grass plots operated against the development of the associated stylo seedlings, except that purple-topped Guinea allowed more light to reach the legume, and as a result the stylo population was somewhat higher than with the previous grass.

Stylo-Pennisetum clandestinum.

Kikuyu grass was lightly grazed during March; heavily grazed in June and August; lightly grazed from October to early January; very well grazed down to 2 inches during February, 1942. The short habit of this grass allowed ample light to reach the associated legume, which developed well, and self-regeneration was general.

Stylo-Melinis minutiflora.

Molasses grass was grazed well throughout. After a period of two years numerous seedlings of stylo were present, particularly at the ends of the plots.

Stylo-Paspalum dilatatum.

Paspalum was grazed lightly. A large number of stylo seedlings was present in these plots at the end of the experiment.

DISCUSSION.

The main object of the trial was to observe the behaviour of stylo under grazing conditions in association with a number of grasses. It appears that the legume shows promise of persisting in association with only two of the grasses under trial, namely Para grass and Kikuyu grass. This observation excludes molasses grass and paspalum, concerning which more evidence is required before any conclusion can be reached.

The trial indicated that stylo can be grazed satisfactorily once stock have acquired a taste for it, and that it will withstand heavy grazing and trampling even after heavy and sustained rainfall. Its palatability appears to vary considerably with the stage of growth. Under grazing, stylo is succulent and grows fairly close to the ground. Refoliation after grazing is good.

Stylo seeds freely for approximately two to three months, and sparingly for a longer period, which varies according to seasonal conditions. Its aggressiveness and self-regenerative powers indicate that it is worthy of consideration for achieving a phase of legume dominance on some of the poorer types of frost-free country in coastal northern Queensland as a first step towards building up soil fertility.

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